

Blackwell's Five-Minute Veterinary Consult
Clinical Companion



Small Animal Emergency and Critical Care



Edited by Elisa M. Mazzaferro

 WILEY-BLACKWELL

**Blackwell's Five-Minute
Veterinary Consult
Clinical Companion**

Small Animal Emergency and Critical Care

Editor

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 **WILEY-BLACKWELL**
A John Wiley & Sons, Inc., Publication

Edition first published 2010
© 2010 Blackwell Publishing Ltd.

Blackwell Publishing was acquired by John Wiley & Sons in February 2007. Blackwell's publishing program has been merged with Wiley's global Scientific, Technical, and Medical business to form Wiley-Blackwell.

Editorial Office
2121 State Avenue, Ames, Iowa 50014-8300, USA

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Library of Congress Cataloging-in-Publication Data

Mazzaferro, Elisa M.

Blackwell's five-minute veterinary consult clinical companion. Small animal emergency and critical care /
Elisa M. Mazzaferro.

p. ; cm. – (Five-minute veterinary consult series)

Other title: Five-minute veterinary consult clinical companion. Small animal emergency and critical care

Other title: Small animal emergency and critical care

Includes bibliographical references and index.

Summary: "Written as a condensed handbook with concise bullet points and topics organized alphabetically, Blackwell's Five-Minute Veterinary Consult Clinical Companion: Small Animal Emergency and Critical Care maintains the acclaimed Five-Minute Veterinary Consult format for quick reference to important information in a fast-paced emergency room or critical care environment. Topics have been pulled from the Five-Minute Veterinary Consult: Canine and Feline and have been expanded to provide additional information, as well as valuable clinical images and useful diagrams. Contents include cardiorespiratory and neurologic conditions; reproductive, ophthalmic, and renal/urologic emergencies; acute problems of the digestive track; metabolic disorders; toxicology; infectious diseases; hepatology; hematology; and other problems such as hypothermia, heat stroke and near-drowning. This text serves as an ideal purchase for general veterinary practitioners and students, veterinary technicians, and hospital and emergency clinic staff"--Provided by publisher.

ISBN 978-0-8138-2043-9 (pbk. : alk. paper) 1. Veterinary emergencies--Handbooks, manuals, etc

I. Title. II. Title: Five-minute veterinary consult clinical companion. Small animal emergency and critical care. III. Title: Small animal emergency and critical care. IV. Series: Five minute veterinary consult.

[DNLM: 1. Emergency Treatment--veterinary--Handbooks. 2. Animal Diseases--therapy--Handbooks.

3. Critical Care--methods--Handbooks. 4. Emergencies--veterinary--Handbooks. SF 778 M477b 2010]
SF778.M39 2010

636.089'6025--dc22

2010012035

A catalog record for this book is available from the U.S. Library of Congress.

Set in 10.5/13 pt Berkeley by Toppan Best-set Premedia Limited
Printed in Singapore

Dedicated to my family at Wheat Ridge Animal Hospital—

You are the best.

Love, “Mazz”

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Preface



The discipline of emergency and critical care is exciting, fast-paced, and often does not allow itself the time for methodical thinking and analysis. The founding members of the American College of Veterinary Emergency and Critical Care and the Veterinary Emergency and Critical Care Society saw the need to constantly advance the knowledge of pathophysiology, the use of technical equipment for diagnostics and patient monitoring, and our skills as veterinarian clinicians and educators. Since that time, the role of the veterinary technician and technician specialist and the team approach to patient care have further allowed exponential improvements in the care of the emergent and critically ill patient. The founding members' insight, motivation, and dedication to emergency and critical care have allowed us to become the veterinarians and technicians that we are in today's veterinary climate.

There are numerous textbooks that are dedicated to emergency and critical care and internal medicine. In a busy emergency department (ED) or critical care unit (CCU), quick thought and rapid timing are often essential parts of making a diagnosis, formulating then implementing an appropriate treatment strategy, and offering a prognosis to our clients. For these reasons, specific topics from the original *Five-Minute Veterinary Consult* have been chosen and expanded to provide you with a quick reference and support tool for the busy ED or CCU, or for the general practitioner faced with an emergency.

This textbook is divided into subjects by content and is organized in alphabetical order. Each subject heading is also listed in alphabetical order in the Contents and by subject in the Contents by Systems and in the index as well. The subject matter presented in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline* has been expanded to include color photographs and flow diagrams with figure captions wherever possible. Additionally, the details of each topic have been updated to include the latest state-of-the-art information provided by leading experts in their fields.

I have been very privileged to work with more than sixty-five veterinarians, many of whom are board certified in Emergency and Critical Care, Internal Medicine, Surgery, Ophthalmology, Anesthesia, and Toxicology. My hope is that your copy of this textbook quickly becomes wrinkled and cracked from frequent use. A book with a tattered cover is well used and well loved. Read with enthusiasm, learn with greed, and take the best care of our patients that you can.

Most sincerely,

Elisa M. Mazzaferro

Acknowledgments



This textbook could not have come to fruition without the hard work, expertise, and contributions of the authors, who, by their dedication and knowledge, provided you with the most current information on the topics related to emergency and critical care.

A very special thanks to the editors, Justin Jeffries, Nancy Simmerman, and Erin Gardner, who first approached me with the idea of this textbook. They, along with the staff at Wiley-Blackwell, supported me with patience and guidance throughout the long journey from start to finish, for which I am very grateful.

Throughout the years, I have been privileged to work with numerous veterinary residents, interns, and students whose thirst for knowledge and quest for “THE answer” have not only kept me young, but also kept me on my toes!

Finally, my most heartfelt thanks and gratitude to the superb veterinarians and veterinary nurses with whom I have worked over the years, including the Animal Emergency Center in Glendale, Wisconsin; Colorado State University; and Wheat Ridge Animal Hospital. Through their eyes, ears, and hands I have acquired immense quantities of knowledge and have been taught the skills and compassion of emergency and critical care.

Acetaminophen Toxicity



DEFINITION/OVERVIEW

- Acetaminophen (paracetamol) is a common over-the-counter pain medication.
- Acetaminophen possesses antipyretic and analgesic properties similar to NSAIDs, although it does not have any anti-inflammatory properties.
- Acetaminophen is found in over two hundred over-the-counter and prescription medications.

BOX 1.1

Tylenol

Children's Tylenol: 80mg acetaminophen

Regular Strength Tylenol: 325mg acetaminophen

Extra Strength Tylenol: 500mg acetaminophen

Opioid and acetaminophen combination products

Vicodin: hydrocodone and paracetamol (acetaminophen)

Percocet: oxycodone and paracetamol (acetaminophen)

Midol® and Pamprin® contain acetaminophen.

Many "cold and sinus" products contain acetaminophen.

Sudafed® cold and sinus

Sudafed® sinus headache

Comtrex® maximum strength sinus and nasal decongestant (with chlorpheniramine and pseudoephedrine)

Vicks Dayquil® multi-symptom cold and flu (with dextromethorphan and pseudoephedrine)



ETIOLOGY/PATHOPHYSIOLOGY

- Metabolized by the liver via two pathways:
 - The major pathway converts acetaminophen to inactive metabolites through conjugation to inactive glucuronide and sulfate metabolites.
 - The minor pathway metabolizes acetaminophen by the p-450 mixed function oxidase to a highly reactive toxic metabolite, NAPQI.
 - Under normal circumstances this minor route produces little NAPQI, but in the event of acetaminophen toxicity, the glucuronidation pathway becomes saturated and metabolism shifts to the production of NAPQI.

- Under nontoxic conditions, glutathione is conjugated to NAPQI, which effectively detoxifies it. In toxic conditions, glutathione stores quickly become depleted, leaving NAPQI free to bind to lipid in the hepatocyte membrane and causing hepatocellular necrosis.
- NAPQI also causes severe oxidative damage to red blood cells by causing the oxidation of hemoglobin to metHb, a compound that does not carry oxygen. Oxidation of hemoglobin also causes the formation of Heinz bodies.
- Cats lack glucuronyl transferase, which decreases the amount of metabolism through the major pathway.
- In cats, relatively smaller amounts of acetaminophen will produce more toxic metabolite and therefore cause more severe toxicity compared to dogs.
- Feline hemoglobin is also unique and contains eight sulfhydryl groups. Because of this unique property, feline hemoglobin is more sensitive to oxidation and can form metHb more rapidly with smaller amounts of acetaminophen.
- In cats, methemoglobinemia may happen rapidly and become fatal before they show signs of hepatotoxicosis.

Systems Affected

- Hepatobiliary: liver necrosis
- Cardiovascular: facial and paw edema (Figure 1.1)
- Hemic/lymphatic/immune: Depletion of glutathione causes oxidative damage to red blood cells and converts hemoglobin to metHb



■ **Figure 1.1** Facial edema may be seen in dogs, but it is more commonly seen in cats with acetaminophen toxicity.

Genetics

- Toxicity is observed in cats more frequently seen than dogs due to their smaller body size and decreased ability to glucoronidate and eliminate acetaminophen.

Incidence/Prevalence

- Most common drug toxicity in cats
- Less common in dogs

**SIGNALMENT/HISTORY****Species**

- Most frequently cats, less commonly dogs
- No known breed predilections

History

- Administration of acetaminophen or history of ingestion of acetaminophen. Owners may not be aware that acetaminophen has potentially life-threatening effects in dogs and cats.
- Owners may notice clinical signs within 1 to 4 hours after ingestion or signs may be delayed until after methHb or hepatotoxicity occurs.

Physical Examination Findings

- Anorexia, salivation, vomiting, abdominal pain
- Hypothermia
- Depression, weakness, coma in severe cases
- Methemoglobinemia
- Brown or cyanotic mucous membranes
- Tachypnea
- Respiratory difficulty/distress
- Dark, chocolate-colored blood and urine
- Edema of the face and paws (most commonly in cats, observed more rarely in dogs)
- Death

Risk Factors/Causes

- Acetaminophen overdose



DIFFERENTIAL DIAGNOSIS

- Other drugs/toxicities causing methemoglobinemia:
 - Nitrites
 - Phenacetin
 - Nitrobenzene
 - Phenol and cresol compounds
 - Sulfites
 - Naphthalene
 - Resorcinol in cats
 - Pyridium
 - Local anesthetics
 - Garlic or onions



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Heinz bodies, especially in cats
- Possibly anemia due to lysis of affected red blood cells
- Elevated ALT, Alk Phos
 - Liver values may increase 24 to 36 hours post-ingestion.
- Elevated total and direct bilirubin
- Serum may be icteric
- Large doses may be nephrotoxic; may see increases in BUN and creatinine
- May see orange or dark colored urine with hemoglobinuria or methemoglobinuria

Other Laboratory Tests

- Arterial blood gas
 - Methemoglobinemia is suspected with dark-colored blood that has a normal or high PaO₂.
 - May show a metabolic acidosis
- Schirmer tear test
 - Idiosyncratic reaction has been shown to cause KCS
 - Sometimes seen at doses below the toxic dose
 - Smaller dogs may be more susceptible
- Acetaminophen serum levels
 - Can be measured at many human hospitals
 - Highest level occurs 1 to 3 hours after ingestion
- Estimate metHb
 - Place a drop of blood on white filter paper; it looks brown if metHb is >15 percent.

- Normal <1 percent
- 20 to 40 percent metHb causes respiratory difficulty
- 40 to 55 percent metHb causes neurologic depression
- 70 percent metHb is acutely life-threatening

Toxic Dose

Dogs

- 100 mg/kg is hepatotoxicity
- 200 mg/kg and methemoglobinemia may be seen

Cats

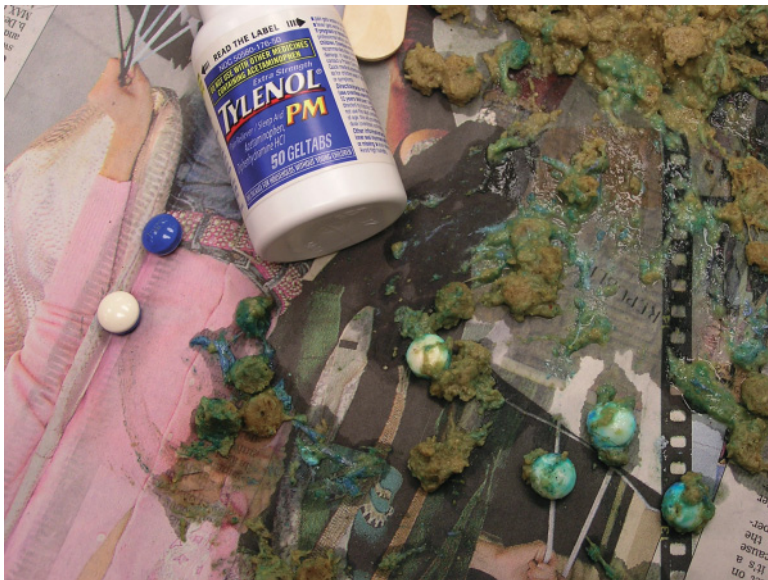
- No safe dose for cats; 10 mg/kg has produced toxic signs, although generally not seen until 30 to 40 mg/kg. Cats generally show severe signs of methemoglobinemia rather than hepatotoxicosis.



THERAPEUTICS

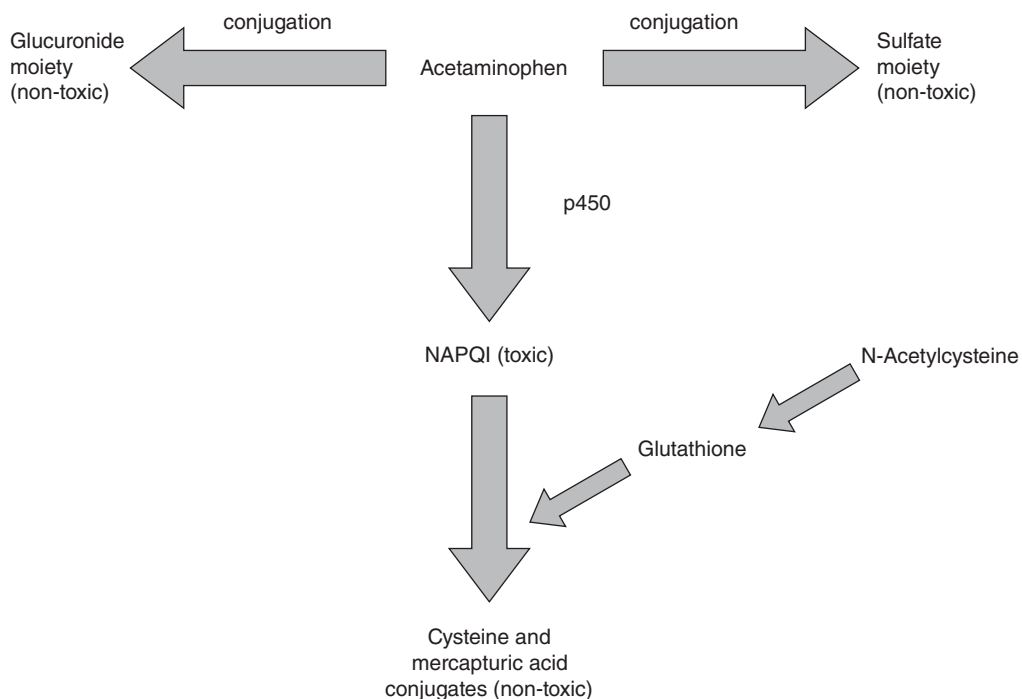
Drug(s) of Choice

- Induction of emesis (Figure 1.2)
 - Apomorphine: 0.03 mg/kg to 0.04 mg/kg IV, IM, or 1.5 to 6 mg dissolved in the conjunctival sac



■ **Figure 1.2** Vomitus containing Tylenol PM that contains acetaminophen.

- Xylazine: 0.44 to 1.1 mg/kg IM or SQ
- Hydrogen peroxide: 1 to 2 ml/kg PO (max dose of 30 ml). If not successful in 10 minutes give another dose once.
- Gastric lavage
 - If emesis is unsuccessful or contraindicated (if animal is neurologically inappropriate or has decreased gag reflex)
- Activated charcoal
 - Repeat every 3 to 4 hours; acetaminophen undergoes enterohepatic recirculation
 - 2 to 5 g/kg
- N-acetylcysteine (Mucomyst)
 - 140 mg/kg PO or IV loading dose
 - 70 mg/kg PO or IV every 6 hours for seven treatments
 - Consider giving 240 mg/kg PO or IV as a loading dose in severe cases
 - Activated charcoal inactivates N-acetylcysteine if it is given PO. Wait at least 30 to 60 minutes between treatments
 - Provides sulfhydryl source to bind NAPQI, and thus protects hepatocytes and red blood cells (Figure 1.3)
 - If intravenous dose, give slowly through bacteriostatic filter



■ **Figure 1.3** Metabolism of acetaminophen to both toxic and non-toxic by-products. In acetaminophen toxicity, the conjugation pathways become saturated and lead to increased p450 metabolism to N-acetyl-para-benzoquinoneimine (NAPQI), the toxic metabolite. Toxicity also leads to glutathione depletion which perpetuates hepatic damage and also contributes to oxidative damage of red blood cells. N-acetylcysteine helps get rid of NAPQI through conjugation to nontoxic by-product.

- Vitamin C (ascorbic acid)
 - 30 mg/kg PO or SQ every 6 hours
 - Questionable efficacy
 - May cause gastrointestinal upset
- Cimetidine
 - 5 to 10mg/kg every 6 to 8 hours IV, IM
 - Reduces metabolism of acetaminophen by the cytochrome p-450 oxidative system in the liver
 - Use as adjunct to N-acetylcysteine
- Supportive therapy
 - Intravenous fluids
 - \pm O₂ therapy
 - \pm Packed red blood cells or whole blood if necessary
 - Feed cats kitten food due to increased sulfhydryl group substrates
- S-adenosyl methionine (sAMe; denosyl)
 - 18mg/kg PO every 24 hours on an empty stomach
 - Chronic treatment until liver enzymes are within normal limits
- \pm Artificial tears; KCS may occur

Contraindications

- Drugs that may perpetuate clinical signs

Precautions/Interactions

- Drugs that are metabolized by the liver may have prolonged half-lives; drugs that are biotransformed by the liver may be less effective.

Activity

- Activity should be restricted.

Appropriate Health Care

- Evaluate immediately when presented with brown or cyanotic mucous membranes,

Nursing Care

- Gentle handling is imperative for clinically affected animals. It is important to minimize stress as much as possible, especially in cats.
- Animals presenting in respiratory distress may require immediate oxygen supplementation.



COMMENTS

Client Education

- Clients should be aware that treatment in severe cases may be prolonged and expensive.
- Affected animals may have residual liver damage.

Patient Monitoring

- Monitor liver enzymes every 12 to 24 hours initially.

Prevention/Avoidance

- Drugs that are metabolized by the liver may have prolonged half-lives.
- Never give acetaminophen to cats.
- Be very cautious when giving acetaminophen to dogs.

Possible Complications

- Liver necrosis and fibrosis
- Death

Expected Course and Prognosis

- Clinical signs may persist for 12 to 48 hours.
- Rising liver enzymes 12 to 48 hours after ingestion raises serious concerns.
- Cats may die as a result of methemoglobinemia up to 36 hours after ingestion.
- Dogs may die of liver failure several days after ingestion.
- Animals receiving prompt attention may expect a complete recovery.
- Prognosis once clinical signs appear is guarded to poor in cats, better in dogs.

Synonyms

- Tylenol
- Paracetamol

Abbreviations

- ALT: alanine aminotransferase
- Alk Phos: alkaline phosphatase
- BUN: blood urea nitrogen
- IM: intramuscularly
- IV: intravenously
- KCS: keratoconjunctivitis sicca
- metHb: methemoglobin
- NAPQI: N-acetyl-para-benzoquinoneimine

- NSAIDs: nonsteroidal anti-inflammatory drugs
- PaO₂: partial pressure of oxygen in arterial blood
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

- Aronson, LR, and Drobatz K. Acetaminophen Toxicosis in 17 Cats. *J Vet Emerg Crit Care* 1996;6:65–69.
- Kore, AM. Toxicology of Nonsteroidal Anti-inflammatory Drugs. *Vet Clin North Am Small Anim Pract* 1988;20(2):419–428.
- Mariani, CL, and Fulton Jr., RB. Atypical Reaction to Acetaminophen Intoxication in a Dog. *J Vet Emerg Crit Care* 2001;11:123–126.
- Oehme, FW. “Acetaminophen Toxicity” in *The 5-Minute Veterinary Consult: Canine and Feline*, 2nd ed., pp. 398–399. Baltimore: Lippincott Williams & Wilkins, 2000.
- Oehme, FW. Aspirin and Acetaminophen. In Kirk, RW, *Current Veterinary Therapy IX*, pp.188–190. Philadelphia: WB Saunders, 1986.
- Plumb, DC. *Veterinary Drug Handbook*, 4th ed. Ames: Iowa State University Press, 2002.
- Richardson, JA. Management of Acetaminophen and Ibuprofen Toxicoses in Dogs and Cats. *J Vet Emerg Crit Care* 2000;10:285–291.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Frederick W. Oehme

Acute Renal Failure (ARF)



DEFINITION/OVERVIEW

- Defined as a sudden reduction in renal function that results in an accumulation of uremic toxins and metabolic waste products.
- These changes are represented by a sudden increase in BUN and creatinine, loss of urine concentrating ability, and acid-base and electrolyte derangements.



ETIOLOGY/PATHOPHYSIOLOGY

- ARF is classically defined by four phases:
 - Initiation, extension, maintenance, and recovery phases mark the progression through all types of renal damage.
 - Initiation occurs during the initial insult, which leads to a progressive decline in renal function over hours to days. This causes renal tubular ischemia, tubular cell sloughing and obstruction, and an associated drop in glomerular filtration and ultrafiltrate production.
 - Extension
 - Marks progression through cellular injury to death and overlaps with the maintenance phase.
- Maintenance
 - Establishes irreversible epithelial damage with a decreased GFR, urine output, and renal blood flow.
- Recovery
 - The urine output increases and there is a progressive resolution in the azotemia. Recovery depends on removal of tubular debris, replication of viable cells, and recovery of GFR.
 - Azotemia does not result until >75 percent of the renal function is lost.
 - The kidney can adapt to a significant loss in tubular function before labwork changes are detectable. Because the kidneys receive approximately 20 percent of the cardiac output, and some substances are concentrated in the renal tubules, nephrotoxins can cause severe damage at low doses. In both toxic and hypoxic injury to the kidneys, the proximal tubule is the most severely affected.

Systems Affected

- Renal/Urologic: acute tubular necrosis, glomerulonephritis
- Gastrointestinal: uremic gastritis, gastrointestinal ulceration, hypergastrinemia, enteritis
- Hematologic: decreased erythropoietin production leading to anemia, thrombocytosis
- Endocrine/metabolic: hyperkalemia, hyper- or hyponatremia, metabolic acidosis, renal hyperparathyroidism
- Hepatic: hepatorenal syndrome (not proven to occur in animals)
- Neurologic: uremic encephalitis
- Respiratory: uremic pneumonitis
- Cardiovascular: hypertension, pericarditis
- Musculoskeletal: ataxia, seizures, muscular weakness



SIGNALMENT/HISTORY

- There is no specific signalment or history that is common among all patients with ARF. There are no sex, breed, or age predilections. Geriatric animals are at higher risk due to concurrent disease processes.

Risk Factors/Causes

- Pre-existing renal disease
- Dehydration
- Shock
- Hypotension
- Toxin exposure (ethylene glycol, heavy metals, Easter lily)
- Sepsis/MODS
- Nephrotoxic medications (e.g., aminoglycosides, amphotericin B, cisplatin)
- Trauma
- Pancreatitis
- Anesthesia or surgery
- Systemic hypertension
- Advanced age
- Intravenous contrast use in diagnostic imaging
- Hypoadrenocorticism
- Myoglobinuria/hemoglobinuria
- Vasculitis
- Thromboembolism
- Infectious disease (e.g., leptospirosis, Rocky Mountain spotted fever, borreliosis)



CLINICAL FEATURES

- Clinical signs can be nonspecific but include most commonly anorexia, lethargy, PU/PD, vomiting, hypotension, and abdominal pain.
- Azotemia with dilute urine (USG <1.020) is seen with or without oliguria (urine output <0.5 to 1 ml/kg per hour) depending on the degree of renal dysfunction and dehydration.
- On physical examination dehydration is the most consistent finding; hypothermia, lingual or oral ulceration, painful enlarged kidneys, and melena are also commonly seen.



DIFFERENTIAL DIAGNOSIS

- Prerenal versus intrinsic renal versus postrenal causes are important to differentiate for treatment and prognosis.
 - Prerenal causes have concentrated urine (USG > 1.030 in dogs and >1.035 in cats), azotemia, dehydration and should resolve with rehydration.
 - Postrenal causes may have palpably enlarged, nonexpressible bladder in urethral obstruction, ureteral obstructions, or uroabdomen detectable through radiographs and ultrasound. Distinguished through physical examination and initial diagnostics.
- ARF or CRF: an acute worsening in pre-existing chronic renal disease. May see partial resolution in azotemia with treatment and rehydration. Persistent azotemia with isosthenuria, weight loss, anemia, and electrolyte alterations are commonly seen. Inciting causes may include dehydration, gastrointestinal disease, pancreatitis, or pyelonephritis so underlying cause for acute worsening should be investigated.
- Hypoadrenocorticism: Causes a prerenal azotemia with isosthenuria due to inability to concentrate urine. Differentiated through electrolyte changes (i.e., hyponatremia, hyperkalemia, hypoglycemia, absence of a stress leukogram) and ACTH stimulation test.
- Hepatorenal syndrome: Documented in humans but not proven to occur in animals. May potentially occur rarely in animals with advanced liver disease or failure.



DIAGNOSTICS

Complete Blood Count/Chemistry

- Urinalysis/USG
- Urine culture and sensitivity
- Abdominal radiographs

- Abdominal ultrasound
- Contrast nephropyelogram
- Excretory urogram
- Renal biopsy
- Ethylene glycol testing
- Serology for infectious diseases (e.g., leptospirosis, borreliosis [in dogs])
- FeLV/FIV (in cats)

Pathologic Findings

- Variable degrees of nephrosis or nephritis, tubular epithelial necrosis, obstructive tubular casts, focal tubular necrosis, interstitial edema and fibrosis, inflammatory cell infiltration, or tubular regeneration.



THERAPEUTICS

Drug(s) of Choice

Fluid Therapy

- Intravenous fluids usually indicated unless hospitalization is not an option. Crystalloid therapy aims to rehydrate, restore intravascular volume, induce diuresis and restore electrolytes using a balance isotonic fluid (NaCl 0.9%, Norm-R, P-Lyte). Intravenous fluids are continued until rehydration occurs and renal values normalize or plateau.

Mannitol

- Used as an osmotic diuretic to improve urine output; potential additional benefits are the flushing of renal tubules from cellular debris/casts and free radical scavenging. It is necessary to ensure that the patient is rehydrated prior to starting therapy and mannitol should be avoided if anuric or hypervolemic because the associated volume expansion will worsen volume overload.

Antibiotics

- Indicated if urinary tract infection, pyelonephritis, or infectious disease, such as leptospirosis or borreliosis, is suspected. Penicillins, such as ampicillin or doxycycline, are the drugs of choice for leptospirosis. Antibiotics for pyelonephritis should be based on urine culture and sensitivity testing.

Furosemide

- Leads to increased urine output in oliguric states. No human or veterinary studies have shown this to improve survival, although they may be beneficial if hemodialysis is not available to allow continued fluid therapy and treat volume overload.



■ **Figure 2.1** Hemodialysis can be used to filter uremic and other toxins from the blood in acute renal failure.

Dopamine

- A low continuous dose of dopamine has previously been documented to improve renal blood flow. No studies have shown survival benefits to this so its use is controversial.

Hemodialysis

- Provides clearance of uremic toxins and removes fluid associated with volume overload to allow the kidneys time to recover function (Figure 2.1). Many toxins are also able to be removed through hemodialysis so early treatment can clear the toxin before active metabolites form preventing renal damage from occurring. Referral to a veterinary specialist that can perform dialysis is indicated if ARF is unresponsive to conventional medical therapy or if the animal is anuric and/or hypervolemic.

Gastric Protectants

- Famotidine (0.5 to 1 mg/kg IM, IV, PO every 24 hours), ranitidine (2 mg/kg IV every 8 to 12 hours), omeprazole (0.7 to 2.0 mg/kg PO every 24 hours in dogs), sucralfate (0.5 to 1 g PO every 6 to 8 hours)

Anti-Emetics

- Ondansetron (0.6 mg/kg IV every 24 hours), dolasetron (0.6 mg/kg IV every 12 to 24 hours), metoclopramide (0.01 to 0.02 mg/kg per hour IV CRI or 0.2 to 0.5 mg/kg SQ, IV, PO every 6 to 8 hours), maripotent (1 mg/kg SQ every 24 hours)

Precautions/Interactions

- To avoid drug toxicities or inadvertent overdosage, care should be taken with reduced doses and extended dosing interval if a medication is excreted through the kidneys.

Alternative Drugs

Diltiazem

- Reports in human medicine show improvement in GFR and urine production through preglomerular dilation; has been documented for CRI use in dogs with leptospirosis but veterinary reports are limited at this time.

Fenoldopam

- Selective dopaminergic-1 receptor agonist used in humans for improved diuresis and urine sodium excretion; shows promise for veterinary patients to improve renal blood flow.

N-acetylcysteine

- Has potential protective benefits against contrast-induced nephropathy if given prior to the contrast being given.

Diet

- Early nutritional support is important in any patient who is critically ill, so unless there is intractable vomiting or nausea, enteral feeding is indicated.
- A moderately protein-restricted diet such as a commercial renal diet is preferred.
- Feeding tube placement (e.g., nasogastric, esophageal, gastric) for nutritional support if the patient is anorectic.
- Parenteral nutrition (i.e., PPN, TPN) may be used to supply a protein-restricted calorie source in cases of intractable vomiting.
- Transition to enteral feeding is preferred as soon as possible.

Surgical Considerations

- Ureterotomy for a complete ureteral obstruction may be indicated dependent on residual kidney function and the extent of the obstruction.



COMMENTS

Client Education

- It is essential to inform the client about the potential for residual renal damage leading to CRF and associated complications.
- Many cases require ongoing treatment, so careful evaluation of the case and discussion on the prognosis are vital.

- Early discussions on referral and hemodialysis in severe cases or toxicities may result in improved outcome and reduce irreversible renal damage so this should be offered early if indicated.

Patient Monitoring

- Close monitoring with serial physical examinations is vital to continuously evaluate hydration and volume status and to treat uremic complications as they arise.
- Urine output monitoring with an indwelling urinary catheter is extremely useful to quantify urine production, detect oliguria early, and match fluid administration with urine output to avoid hypervolemia.
- Frequent weighing (every 6 to 8 hours) can also help to detect early fluid retention.
- Regular monitoring every 8 to 12 hours of electrolytes, acid-base status, and renal values should be used to guide fluid therapy and determine if therapy is being effective or if alternative therapies should be considered.

Prevention/Avoidance

- Attempts should be made to avoid any potentially nephrotoxic medications if evidence of prior renal insufficiency or concurrent illness is noted.
- Predisposing factors, such as prolonged anesthesia, hypotension, or hemodynamic compromise, should be minimized where possible, particularly in patients with concurrent disease or other risk factors.

Possible Complications

- Uremic gastritis
- Uremic pneumonitis
- Seizures
- Hypervolemia
- Pulmonary edema
- Gastrointestinal ulceration

Expected Course and Prognosis

- Survival from ARF in animals is dependent on the inciting cause in addition to how prompt and aggressive treatment is.
- Overall mortality ranges from 40 to 60 percent with approximately 50 to 60 percent leading to chronic renal failure.
- In the majority of cases, infectious diseases, such as leptospirosis and nonoliguric cases (of any cause), carry a better prognosis than toxicities or oliguric cases although this is treatment dependent.
- Cases of anuric renal failure are usually fatal unless dialysis is available.

Synonyms

- Acute tubular necrosis
- Acute renal injury
- Acute uremia

Abbreviations

- ACTH: adrenocorticotrophic hormone
- ARF: acute renal failure
- BUN: blood urea nitrogen
- CRF: chronic renal failure
- CRI: continuous rate infusion
- FIV: feline immunodeficiency virus
- FeLV: feline leukemia virus
- FiV: feline immunodeficiency virus
- GFR: glomerular filtration rate
- IV: intravenously
- IM: intramuscularly
- MODS: multiple organ dysfunction syndrome
- PO: by mouth
- PPN: peripheral parenteral nutrition
- PU/PD: polyuria/polydipsia
- SQ: subcutaneously
- TPN: total parenteral nutrition
- USG: urine specific gravity

Suggested Reading

- Ettinger, SJ, and Feldman, EC. *Textbook of Veterinary Internal Medicine*, 6th ed. Vol. 2., pp. 1731–1751. Philadelphia: Elsevier Saunders, 2005.
- Lameire, N. The pathophysiology of acute renal failure. *Crit Care Clin* 2005;21:197–210.
- Nelson, RW, and Couto, CG. *Small Animal Internal Medicine*, 3rd ed., pp.608–623. St. Louis: Mosby, 2003.
- Silverstein, DC, and Hopper, K. *Small Animal Critical Care Medicine*, pp. 590–594. Philadelphia: Saunders Elsevier, 2009.
- Stokes, JE, and Bartges, JW. Causes of Acute Renal Failure. *Compendium of Continuing Education for the Practicing Veterinarian*. 2006;28(5):387–396.

Authors: Ravi Seshadri and Kathryn Crump

Acute Respiratory Distress Syndrome (ARDS)



DEFINITION/OVERVIEW

- ARDS is a severe inflammatory disorder of the lung that can cause respiratory failure in dogs and cats.
- It is a form of noncardiogenic pulmonary edema caused by lung inflammation, cellular infiltration, and capillary leak.
- ALI is a milder form of inflammatory injury to the lungs but can progress to ARDS.



ETIOLOGY/PATHOPHYSIOLOGY

- ALI and ARDS can occur from direct pulmonary insult, or, more commonly in critically ill patients, by a generalized inflammatory response such as SIRS or sepsis.
- In SIRS or sepsis, activation of tumor necrosis factor and pro-inflammatory interleukins initiate inflammatory mediators and activation of neutrophils and macrophages. ARDS is a local pulmonary manifestation of SIRS.
- Pancreatitis can cause lung injury secondary to vascular endothelial damage by activated proteases and associated inflammation.
- Local pulmonary injury can trigger an inflammatory response that can become generalized within the lung parenchyma, with production of pro-inflammatory cytokines by inflammatory cells, lung epithelial cells, and fibroblasts.
- Clinical and histopathologic findings are similar for all etiologies.
- Initial stages begin as a diffuse exudative vascular leak syndrome with infiltration of neutrophils and macrophages and effusion of protein-rich fluid into the alveoli, resulting in progressive pulmonary edema.
- Chemotaxis results in accumulation of inflammatory cells, particularly neutrophils, contributing to ongoing lung injury.
- Continued inflammation and repair attempts result in proliferation of type II pneumocytes, formation of hyaline membranes within alveoli (organization of protein-rich fluid and cellular debris), deficiency of surfactant, and collapse and atelectasis of alveoli.
- This is followed by interstitial fibrosis as the lung attempts to repair the damaged tissue, with inflammatory changes varying in severity and often unevenly distributed in the lung.

- In more severely affected animals, the inflammation is severe and leads to severe hypoxia and death of the patient.

Systems Affected

- Respiratory
- Cardiovascular
- Hemic/Lymphatic/Immune
- Renal/Urologic



SIGNALMENT/HISTORY

Risk Factors/Causes

Systemic Disorders

- SIRS
- Sepsis
- Organ torsion (gastric, splenic)
- Canine parvoviral enteritis
- Pancreatitis
- Severe trauma
- Massive transfusions (reported in humans)

Primary Respiratory Disorders

- Aspiration or bacterial pneumonia
- Pulmonary contusions
- Smoke inhalation
- Noncardiogenic pulmonary edema secondary to strangulation, choking, or seizures
- Multiple etiologies; it may occur as a result of both direct lung injury and SIRS
- Occasionally predisposing factors cannot be identified
- No breed, age, or sex predispositions

Historical Findings

- Most commonly occurs in patients in intensive care unit with other underlying diseases, but may affect other patients, causing presentation with an acute history of severe respiratory distress
- Earliest signs often include progressive hypoxia and tachypnea.
- Usually no history of coughing, but occasionally low-grade productive cough
- Can progress to severe respiratory distress and cyanosis on room air
- Gas exchange may be severely impaired.



CLINICAL FEATURES

- Severe respiratory distress, cyanosis
- Auscultation—harsh lung sounds can rapidly progress to crackles
- Dogs may cough up pink foam.
- If intubated, sanguineous fluid may drain out of the endotracheal tube in both dogs and cats.
- Often are tachycardic from poor oxygen delivery to tissues that results from severe hypoxemia
- Pulmonary edema in an animal with a predisposing cause of inflammatory response without evidence of heart failure



DIFFERENTIAL DIAGNOSIS

- Cardiogenic pulmonary edema
- Volume overload
- Pulmonary thromboembolism
- Bacterial pneumonia
- Atelectasis
- Pulmonary hemorrhage
- Neoplasia



DIAGNOSTICS

Thoracic Radiographs

- Early ALI—often have increased pulmonary interstitial and peribronchial markings
- As ALI progresses to ARDS, diffuse bilateral pulmonary alveolar infiltrates develop throughout all lung fields, may be asymmetrical or patchy, and ventral lung lobes may be most severely affected (Figures 3.1 and 3.2).
- Small volume of pleural effusion may or may not be present.
- Heart and blood vessel size should be normal, otherwise left-sided congestive heart failure may be present rather than ARDS.

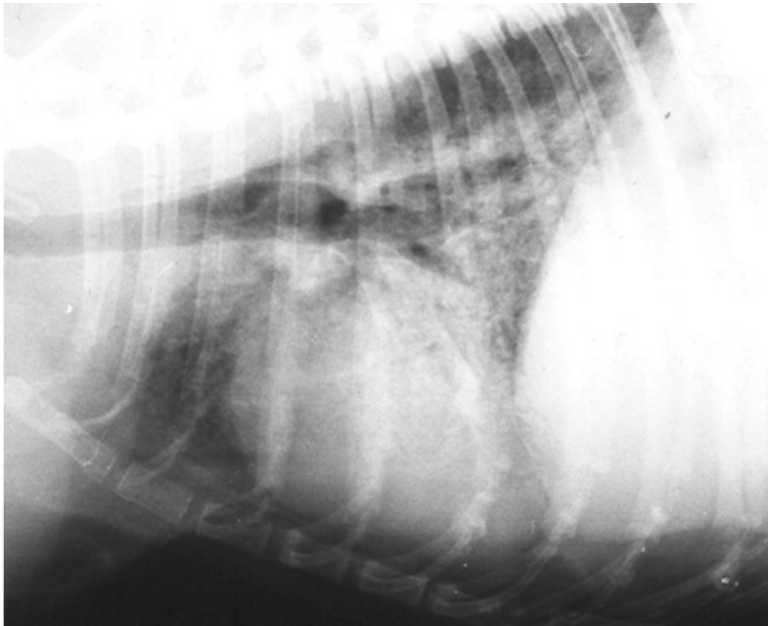
Arterial Blood Gases

- Arterial blood gas—severe hypoxia and usually hypocarbia as hypoxia begins to drive respiration and results in hyperventilation. If end-stage lung disease or respiratory muscle fatigue occurs, may see hypercarbia. Lactic acidosis may be present due to poor oxygen delivery and anaerobic tissue metabolism.
- $\text{PaO}_2:\text{FiO}_2$ ratios are also significantly low (reference range $\sim 430\text{--}560$ mm Hg). Typically, $\text{PaO}_2:\text{FiO}_2$ ratio ≤ 300 is consistent with ALI, whereas $\text{PaO}_2:\text{FiO}_2$ ratio ≤ 200 is consistent with ARDS.

3.1

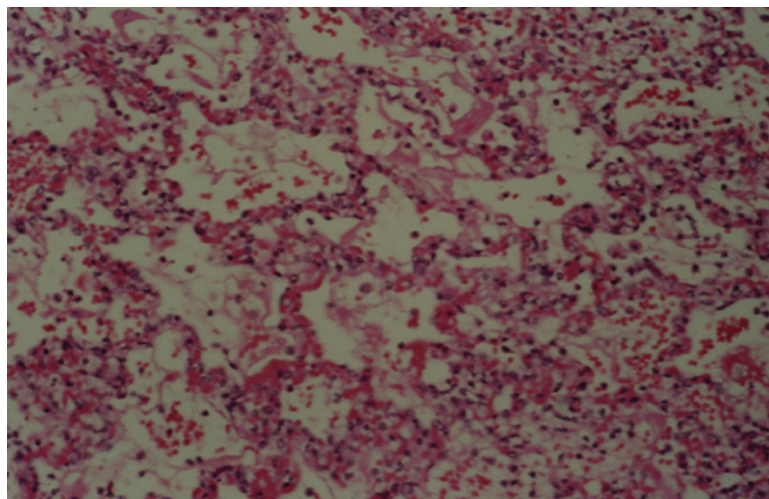


3.2



■ **Figure 3.1 and Figure 3.2** Radiographs of a 6-year-old FS MIXB that presented with increased respiratory rate and effort. She was anesthetized for diagnostic testing, including these thoracic radiographs, which show a diffuse patchy alveolar pattern consistent with acute respiratory distress syndrome. Her oxygenation status continues to decline despite positive-pressure ventilation, so she was euthanized. On necropsy, a diagnosis of severe subacute to chronic interstitial pneumonia with acute respiratory distress syndrome was made.

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■ **Figure 3.3** Histopathology (20×) of the lung of a dog with acute respiratory distress syndrome, diagnosed on postmortem examination. The capillaries are dilated and filled with red blood cells and the alveoli contain a mixture of red cells, neutrophils, macrophages, and strands of fibrin.

Courtesy of Dr. Tom Van Winkle, Laboratory of Pathology, University of Pennsylvania. Reprinted with permission from *The Veterinary ICU Book*, Teton NewMedia.

Complete Blood Count/Biochemical/Coagulation

- Leukopenia due to sequestration of white blood cells in periphery and in lungs
- Thrombocytopenia due to platelet sequestration or consumption
- Consumptive coagulopathy may be manifested by prolonged coagulation times and elevated fibrin degradation products or D-dimers.
- Chemistry panel usually has nonspecific changes, but hypoalbuminemia may occur due to underlying disease and exudative protein loss into the pulmonary edema fluid.

Additional Diagnostics

- Elevation of CVP or pulmonary capillary wedge pressure (>18 mm Hg) can also help to suggest congestive heart failure or fluid overload, not ALI or ARDS.
- Pulmonary function testing—poor lung compliance
- Extremely high mean and peak airway pressures needed for PPV
- Pulmonary hypertension may occur in severely affected patients due to obliteration of the pulmonary capillary bed.

Pathologic Findings

- Gross examination—heavy, stiff lungs
- Histology—diffuse alveolar damage, presence of hyaline membranes, congestion, edema, neutrophil infiltration, hemorrhage, local thrombosis, and atelectasis. This is followed by type II pneumocyte proliferation (replacing dead type I pneumocytes), proliferation of fibroblasts, then finally collagen deposition in the alveolar, vascular, and interstitial beds (Figure 3.3).



THERAPEUTICS

- First priority—address the underlying cause of SIRS or primary lung injury to remove source of ongoing injury/prevent repeat injury, if possible.
- Second priority—carefully evaluate fluid therapy to prevent fluid overload and worsened pulmonary dysfunction. Measurement of CVP or pulmonary capillary wedge pressure to aid in fluid therapy to prevent overhydration but maintain euvolemia.
- If volume overload is present, judicious administration of diuretics such as furosemide.
- Colloid support if hypoproteinemic. Can include fresh frozen plasma (provides coagulation factors and acute phase proteins in addition to albumin), synthetic colloids such as hetastarch, and 25 percent human albumin solutions.
- Oxygen supplementation—animals with mild ALI may respond to oxygen supplementation alone, but severe ARDS patients usually require PPV to achieve adequate gas exchange.
- PPV with PEEP recruits alveoli and increases functional residual capacity, allowing ventilation at lower FiO_2 and preventing cyclical alveolar reopening and stretching with each breath. FiO_2 should be ≤ 0.6 to prevent oxygen toxicity and tidal volumes should be as low as possible (ideally 6–8 ml/kg) to prevent overdistention of relatively normal alveoli, shear stress, and progression of lung injury. Excessively high airway pressures ($>30 \text{ cmH}_2\text{O}$) can cause worsening of lung permeability and also produce pneumothorax.

Drug(s) of Choice

- Many treatments have been evaluated experimentally in animal models and clinically in humans with ARDS. These include corticosteroids, albumin solutions, furosemide, N-acetylcysteine, pentoxifylline, surfactant, and a variety of cyclooxygenase, thromboxane, and leukotriene inhibitors. Although some appeared promising in canine and feline models of ARDS, none have been shown to have an effect on morbidity or mortality in human clinical trials.
- Antibiotics if appropriate for underlying disease
- Diuretics if volume overload or cardiac disease is suspected, but will not be beneficial if pulmonary edema is due to ALI or ARDS alone. Careful if patient is hypovolemic; may worsen cardiovascular status.
- Supportive measures as required by patient: fluid therapy, pressors if indicated, and anesthesia to allow for PPV
- Corticosteroids have been recommended in late, proliferative stage of ARDS (5–7 days), but has not been substantiated by scientific data.



COMMENTS

Patient Monitoring

- Patients require intensive care monitoring with frequent arterial blood gas analysis, pulse oximetry, arterial blood pressure, urine output, temperature, ECG, thoracic radiographs, CBC, chemistry, and coagulation monitoring.

Prevention/Avoidance

- Aggressive therapy of underlying disease processes, treating any cardiovascular compromise
- Prevention of aspiration pneumonia through careful use of analgesics and sedation and appropriate nursing care

Possible Complications

- Respiratory failure and death
- Progressive multiple organ dysfunction and failure (DIC, renal, gastrointestinal, and hepatic)

Expected Course and Prognosis

- Humans with ARDS have an expected survival rate of 40 to 60 percent and often require mechanical ventilation for 4 to 6 weeks.
- Mortality in dogs and cats is even higher, and a grave prognosis must be given.

Synonyms

- Shock lung
- Traumatic wet lung
- Adult hyaline membrane disease
- Capillary leak syndrome

Abbreviations

- ALI: acute lung injury
- ARDS: acute respiratory distress syndrome
- CBC: complete blood count
- CVP: central venous pressure
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- PEEP: positive end-expiratory pressure
- PPV: positive pressure ventilation
- SIRS: systemic inflammatory response syndrome

Suggested Reading

- Bernard, GR, Artigas, A, Brigham, KL, et al. Report of the American-European Consensus Conference on Acute Respiratory Distress Syndrome: definitions, mechanisms, relevant outcomes, and clinical trial coordination. *J Crit Care* 1994;9(1):72.
- DeClue, AE, and Cohn, LA. Acute respiratory distress syndrome in dogs and cats: a review of clinical findings and pathophysiology. *J Vet Emerg Crit Care* 2007;17(4):340.
- Parent, C, King, LG, Van Winkle, TJ, and Walker, LM. Clinical and clinicopathologic findings in dogs with acute respiratory distress syndrome: 19 cases (1985–1993). *J Am Vet Med Assoc* 1996;208(9):1419.
- Parent, C, King, LG, Van Winkle, TJ, and Walker, LM. Respiratory function and treatment in dogs with acute respiratory distress syndrome: 19 cases (1985–1993). *J Am Vet Med Assoc* 1996;208(9):1428.
- Ware, LB, and Matthay, MA. The acute respiratory distress syndrome. *N Eng J Med* 2000;342(18):1334.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Kate Hopper

Amitraz Toxicity



DEFINITION/OVERVIEW

- Amitraz is applied topically to control ticks, mites, and lice.
- Products containing amitraz for dogs are formulated as a 19.9 percent emulsifiable concentrate in 10.6-ml bottles for dilution and application as a topical pour on and as a 9.0 percent impregnated twenty-five-inch 27.5-g collar.
- The pesticide is found in Preventic® flea and tick collars, ProMeris® topical spot-on treatment (for dogs), and in external lotions and dip (Mitaban®) used to treat demodectic mange.
- Flea and tick collars contain enough amitraz to cause clinical signs of intoxication in a twenty-five-pound dog.



ETIOLOGY/PATHOPHYSIOLOGY

- Amitraz affects peripheral α_1 - and α_2 -adrenergic receptor sites in the cardiovascular system and α_2 -adrenergic receptor sites in the CNS, thus it is a α_2 -adrenergic agonist.
- Toxic exposure can occur either through the oral or dermal route.
- After high dose, oral ingestion peak plasma concentration is reached at 6 hours and elimination half-life is as long as 24 hours.
- The metabolites are excreted in the urine.

Systems Affected

- Nervous via peripheral- α -adrenergic agonistic action causing depression and ataxia
- Cardiovascular via α -adrenergic agonistic action causing bradycardia and hypotension
- Gastrointestinal causing vomiting, diarrhea, and abdominal pain



SIGNALMENT/HISTORY

- Toxicity in dogs is more commonly reported than in cats or other species.
- Amitraz should *never* be used in cats.

Risk Factors/Causes

- Increased predilection for toxicity in geriatric, sick, or toy breed animals

Historical Findings

- Signs of sudden collapse, depression, vomiting, and diarrhea



CLINICAL FEATURES

- Neurological signs as depression, ataxia, and weakness
- Cardiovascular collapse with bradycardia, recumbency, and hypotension
- Gastrointestinal signs of vomiting, diarrhea, and abdominal pain



DIFFERENTIAL DIAGNOSIS

- Recreational and prescription drugs such as marijuana, opioids, barbiturates, benzodiazepines, phenothiazines, antihypertensive drugs, skeletal muscle relaxants, and other depressive drugs
- Ivermectin or milbemycin in very high doses to sensitive breeds
- Alcohols such as ethanol, ethylene glycol (antifreeze), methanol (wind shield washer fluid), isopropyl alcohol (rubbing alcohol)
- Tick paralysis, botulism
- Head trauma
- Cardiovascular collapse



DIAGNOSTICS

Complete Blood Count/Biochemistry

- Hyperglycemia is common.
- Liver enzymes may rarely be elevated.

Imaging

- Abdominal radiology may reveal a collar buckle in the gastrointestinal tract.

Pathological Findings

- High-dose and prolonged exposure shows increased liver weight; slight enlargement of hepatocytes; thinning of the zonae fasciculata and reticularis; slight hyperplasia of the zona glomerulosa of the adrenal glands



THERAPEUTICS

Drug(s) of Choice

- Treatment of amitraz poisoning is best accomplished by gastric decontamination and administration of antidotes (yohimbine or atipamezole).

Contraindications

- Scrub with a hand dish-washing detergent; rinse with copious amounts of warm water; institute nonspecific supportive therapy (e.g., intravenous fluids, maintenance of normal body temperature, nutritional support); monitor 1 to 2 days until improvement is noted.

Precautions/Interactions

- Do not administer atropine, even if bradycardia occurs. Atropine may relieve some clinical signs, however may cause other clinical signs to worsen, and may contribute to hypertension.
- Do not induce emesis if the toxic substance was Mitaban® dip, due to risk of aspiration pneumonia.

Ingestion of Collar; Asymptomatic Patient

- Emetic as 3% USP hydrogen peroxide (2.2 m/kg PO maximum 45 ml after feeding a moist meal); apomorphine, and especially xylazine, not recommended
- Endoscopic retrieval of collar if large segments within the stomach; usually numerous small pieces are located throughout the gastrointestinal tract, making endoscopic removal difficult or unrealistic.
- Surgical removal of collar from gastrointestinal tract
- Activated charcoal (2 g/kg PO) containing sorbitol

Marked Depression

- May require pharmacologic reversal of the α_2 -adrenergic effects
- Yohimbine (Yobine)—0.11 mg/kg IV, administered slowly; reverses depression and bradycardia within minutes; objective is to keep the patient in a state of low-level depression with normal heart rate, blood pressure, body temperature, and blood glucose concentrations
- Collar ingestions—monitor for recurrence of clinical signs; may need additional yohimbine until collar segments appear in the stool
- Atipamezole (Antisedan)—0.05 mg/kg IM; reported to reverse poisoning within 10 minutes; repeated as needed; can be used an alternative when yohimbine is unavailable
- Yohimbine and atipamezole may require initial repeated administration every 4 to 8 hours because half-life in dogs is short and elimination half-life of amitraz is longer.



COMMENTS

Client Education

- No long-term adverse effects expected

Patient Monitoring

- Administer fluids to maintain normal perfusion and hydration.
- Body temperature, blood pressure, serum glucose, and heart rate are important.
- Close observation for recurrence of clinical signs are required for 24 to 72 hours.

Prevention/Avoidance

- Do not use amitraz impregnated collar in dogs prone to ingestion.
- Do not use amitraz on cats.
- Careful use of amitraz topical products especially in animals with known sensitivity.

Expected Course and Prognosis

- Geriatric, sick, or debilitated animals may take longer to fully recover.
- Mildly affected animals may recover spontaneously.
- The prognosis is fair for severely affected animals.

Abbreviations

- CNS: central nervous system
- IM: intramuscularly
- IV: intravenously
- PO: by mouth
- USP: United States Pharmacopeia

Suggested Reading

Duncan, KL. Treatment of amitraz toxicosis. *J Am Vet Med Assoc* 1993;203:1115–1116.

Grossman, MR. Amitraz toxicosis associated with ingestion of an ascaricide collar in a dog. *J Am Vet Med Assoc* 1993;203:55–57.

Hansen, SR. Amitraz toxicosis. In: Tilley, LP, and Smith, FWK, eds. *The 5-minute Veterinary Consult*, 3rd ed., pp. 62–63. Baltimore: Williams & Wilkins, 2004.

Hugnet, C, Buronfosse, F, Pineau, X, et al. Toxicity and kinetic of amitraz in dogs. *Am J Vet Res* 1996;57:1506–1510.

Plunkett, SJ. Amitraz toxicosis. In: Plunkett SJ, ed. *Emergency Procedures for the Small Animal Veterinarian*, 2nd ed., p. 284. Philadelphia: W.B Saunders, 2000.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Steven R. Hansen

Anaphylaxis



DEFINITION/OVERVIEW

- Anaphylaxis is a severe multisystemic type I hypersensitivity reaction, which may include hypotension or airway compromise. It is characterized by the release of vasoactive substances from mast cells and basophils.
- *Anaphylaxis* is a term used when the reaction is mediated by IgE.
- *Anaphylactoid* is the term used for the same clinical syndrome without prior sensitization and without IgE being a mediator. The terms will be used interchangeably in this section.



ETIOLOGY/PATHOPHYSIOLOGY

- A multitude of agents can trigger anaphylaxis. By general type they include:
 - Foods and additives
 - Insect venoms
 - Virtually any drug, blood product, and biological substance
- The basic mechanism underlying type I allergic reactions is massive mast cell and basophil degranulation and mediator release.

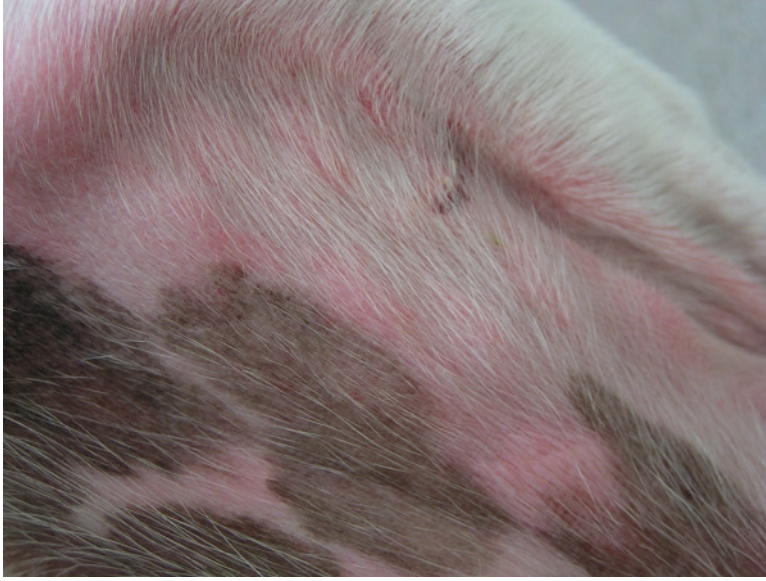
Systems Affected

Dogs

- Major shock organ is the liver with massive splanchnic congestion.
- All other systems affected as a result of the hypovolemia.
- Hemorrhage can also occur as a result of DIC.
- A mild form of anaphylaxis can involve the skin and be manifested as urticaria (Figure 5.1), pruritus, and angioneurotic edema (Figure 5.2).
- The bowel can also be involved and be manifested as vomiting and defecation/diarrhea.

Cats

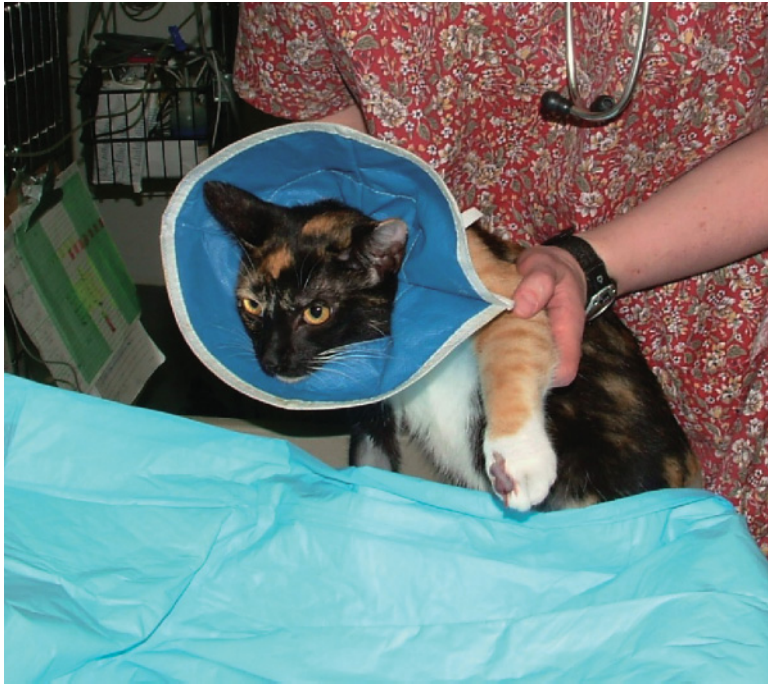
- Major shock organs are the lungs and the intestines (Figures 5.3 and 5.4).
- Hypovolemia and hypoxemia can affect all other organ systems.



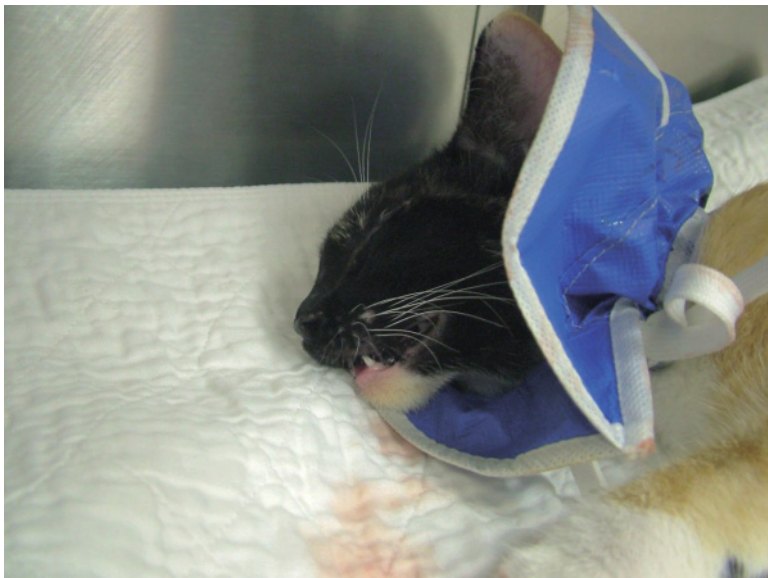
■ **Figure 5.1** Urticaria on ventral abdomen of a dog during a vaccination reaction.



■ **Figure 5.2** Angioneurotic edema in a dog following a bee sting.



■ **Figure 5.3** This young cat was bitten on the front paw by a water moccasin pit viper and was given crotalid polyvalent antivenin intravenously.



■ **Figure 5.4** During the slow injection of the crotalid polyvalent antivenin, the cat became restless and then had all of the classic signs of anaphylaxis (i.e., vomiting, defecation, weakness and hypotension, and shortness of breath).



SIGNALMENT/HISTORY

- There are no sex, breed, or age predilections.

Risk Factors/Causes

- The exposure to any new antigen (anaphylactoid) or previously encountered (anaphylaxis) antigen with or without prior sensitization. Drugs, biological substances, blood products, and toxic venoms are frequent causes.

Historical Findings

- Witnessed envenomation by insect, arachnid, or reptile. In many cases, envenomation is presumed due to clinical signs and lack of known exposure to drugs, blood products, or vaccinations.
- Clinical report of administration of any drug or blood products.
- Clinical signs usually occur within minutes to hours after the exposure to the antigen.



CLINICAL FEATURES

Dogs

- Restless
- Urticaria (see Figure 5.1)
- Angioneurotic edema (see Figure 5.2)
- Nausea
- ±Vomiting
- Diarrhea
- Weakness
- Collapse
- Possibly death

Cats

- Restless
- Sometimes pruritus
- Vocalize
- Vomiting
- Defecation
- Weakness
- Increased respiratory rate
- Bronchoconstriction
- Acute laryngeal dysfunction

- Sometimes pulmonary edema
- Possibly death



DIFFERENTIAL DIAGNOSIS

Dogs

- Any cause of acute hypotension ranging from hemorrhage, thromboembolism, acute myocardial failure, or acute intoxication.

Cats

- Any cause of acute upper airway obstruction, any cause of pulmonary edema, or acute intoxication.



DIAGNOSTICS

- The timing of the occurrence and the clinical signs are the main diagnostic clues.

Pathologic Findings

Dogs

- Hepatic congestion
- Splanchnic congestion
- Gastrointestinal hemorrhage

Cats

- Bronchoconstriction
- Emphysema
- Pulmonary hemorrhage
- Laryngeal edema



THERAPEUTICS

Drug(s) of Choice

- Eliminate sensitizing agent if possible.
- Discontinue use of the suspected drug.
- For severe signs:
 - *Epinephrine* 0.01 mg/kg IM or IV; can repeat every 15 to 20 minutes, if necessary.

- Epinephrine works immediately to cause large vessel vaso- and venoconstriction, which will increase the systemic blood pressure. It is an *essential* and *life-saving* drug for severe anaphylaxis.
- Give epinephrine IM unless there is complete cardiac dysfunction under which circumstance it is given IV. Intravenous epinephrine can be arrhythmogenic.
- Subcutaneous epinephrine is slowly absorbed and inefficient, particularly in animals with hypotension
- Epinephrine will also cause bronchodilatation and decrease bronchoconstriction.
- *Diphenhydramine*—give 1.0 mg/kg IM; can repeat every 12 hours.
 - Works as an antihistamine and blocks H₁ receptors.
- *Ranitidine* at 0.5 to 1.0 mg/kg IV or *famotidine* at 0.5 to 1.0 mg/kg IV every 12 hours.
 - Works as antihistamine and blocks H₂ receptors.
- Antihistamines might be only drug of choice for mild anaphylaxis, but it will *not* substitute for epinephrine for severe anaphylaxis.
- *Glucocorticoids*
 - Actually requires several hours to take effect.
 - Can give
 - Prednisolone sodium succinate 2 to 10 mg/kg initially
 - Dexamethasone 1 mg/kg IM, IV initially
 - Glucocorticoids will antagonize the delayed mechanisms of the allergic reaction.
- Other therapeutic measures might be needed in the most severe form of anaphylaxis. These include:
 - Volume expanders such as intravenous saline, lactated Ringer's, or Normosol-R.
 - Colloids such as hydroxyethyl starch—give colloids slowly to cats over a several-hour period at a dose of 5 to 10 ml/kg.
 - Dogs can receive up to 20 ml/kg over a 2- to 3-hour period under emergent conditions, or 5 to 10 ml/kg as a fast bolus; otherwise it should be given at a slower rate over a 24-hour period.
- Vasopressors
 - Dopamine 5 to 10 µg/kg per min IV
- Bronchodilators—for cats
 - Albuterol—can use inhaler with rebreathing device
 - Terbutaline 0.01 mg/kg IM, IV
- Oxygen
- All animals with anaphylaxis must be hospitalized under intensive care conditions.

Precautions/Interactions

- Epinephrine given IV can be arrhythmogenic.
- Patient should have ECG and blood pressure monitoring.

Alternative Drugs

- Remember that there is no substitute drug for epinephrine in severe anaphylaxis.

Diet

- Avoid any food that might be a sensitizing agent.

Activity

- No restrictions necessary.

Surgical Considerations

- Anaphylaxis occurring during surgery can be fatal.
- It should be considered when there is a sudden and unexplainable decline in blood pressure.



COMMENTS

Client Education

- Avoid pet from encountering any known sensitizing agent.

Patient Monitoring

- ECG
- Blood pressure
- Urine output
- Respiratory rate and effort
- Weight and hydration status if vomiting or diarrhea present
- Physical examination for urticaria or angioneurotic edema

Prevention/Avoidance

- Crisis situation requires monitoring of all vital signs.
- Might instruct on home use of epinephrine injection in cases of insect envenomations in previously sensitized animals.

Possible Complications

- Death

Expected Course and Prognosis

- Possible relapses.
- Prognosis excellent with uneventful recovery.

Synonyms

- Massive allergic reaction
- Type I hypersensitivity
- Anaphylactoid
- Peracute hypersensitivity

Abbreviations

- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- IgE: Immunoglobulin E
- IM: intramuscularly
- IV: intravenously

Suggested Reading

Alrasbi, M, and Sheikh, A. Comparison of international guidelines for the emergency medical management of anaphylaxis. *Allergy* 2007;62:838–841.

Fitzgerald, KT, and Flood, AA. Hymenoptera stings. *Clin Tech Sm Anim Pract* 2006;21(4):194–204.

Johnson, RF, and Peebles, Jr RS. Anaphylactic shock: pathophysiology, recognition and treatment. *Semin Respir Crit Care Med* 2004;25(6):695–703.

Rowe, BH, and Carr, S. Anaphylaxis and acute allergic reactions. In: Tintinalli, JE, Kelen, GD, and Stepczynski, JS, eds. *Emergency Medicine—A Comprehensive Study Guide*, 6th ed., pp. 247–251. New York: McGraw-Hill, 2004.

Tizzard, IR. Type I hypersensitivity. In: Tizzard, IR, ed. *Veterinary Immunology—An Introduction*, 7th ed., pp. 308–323. Philadelphia: Saunders-Elsevier, 2004.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Paul W. Snyder

Anterior Uveitis



DEFINITION/OVERVIEW

- Uveitis is a general term for inflammation in any portion of the uveal tract, regardless of cause.
- Anterior uveitis is inflammation of the iris and ciliary body.
- Posterior uveitis is inflammation of the choroid, usually with concurrent inflammation of the retina (chorioretinitis).



ETIOLOGY/PATHOPHYSIOLOGY

- Intraocular inflammation is initiated by local tissue injury (e.g., trauma, infectious agent, immune mediated, neoplasia).
- Bilateral anterior uveitis often indicates an underlying systemic disease process.
- Damaged tissue and microorganisms release tissue factors and inflammatory mediators that cause vasodilation and increased vascular permeability.
- The result is disruption of the blood-eye barrier, aqueous flare (increased protein in the anterior chamber), and migration of inflammatory cells into the anterior chamber and anterior uveal tissue.
- Causes of uveitis can be exogenous (blunt or penetrating trauma; corneal ulceration or infection) or endogenous (systemic or primary intraocular disease).

Dogs

- Systemic infectious causes—mycotic (blastomycosis, histoplasmosis, coccidiomycosis, cryptococcosis); algal (protothecosis); rickettsial (*Ehrlichia* sp., *Rickettsia rickettsii*); bacterial (brucellosis, borreliosis, any bacterial septicemia); protozoal (*Toxoplasma gondii*, *Leishmania*); viral (infectious canine hepatitis); aberrant parasite migration (fly larvae, nematode larvae)
 - German shepherd dogs are predisposed to disseminated saprophytic fungal infection (*Aspergillus* sp., *Candida* sp., *Penicillium* sp., *Paecilomyces* sp.).
- Immune-mediated/presumed immune-mediated causes—exposure to lens proteins (cataract or lens rupture); uveodermatologic syndrome; idiopathic; uveitis associated with uveal cysts; CAV-1 and CAV-2 vaccine reaction; scleritis
- Neoplastic causes—primary intraocular or metastatic to eye

- Metabolic causes—hyperlipidemia
- Miscellaneous causes—systemic hypertension; hyperviscosity syndrome; lens luxation

Cats

- Systemic infectious causes—viral (FeLV, FIV, FIP, possibly FHV-1); protozoan (*Toxoplasma gondii*, *Leishmania*); bacterial (*Bartonella* sp., any cause of septicemia), fungal (blastomycosis, histoplasmosis, coccidiomycosis, cryptococcosis).
- Immune-mediated/presumed immune-mediated causes—exposure to lens proteins (cataract or lens rupture); idiopathic.
- Neoplastic causes—primary intraocular or metastatic to eye.

Systems Affected

- Ophthalmic



SIGNALMENT/HISTORY

- Anterior uveitis can occur in any dog or cat regardless of age, breed, or sex.
- Because there are many causes for anterior uveitis, the signalment and history of the patient will vary and should be used as a tool to guide the clinician toward a diagnostic plan.

Historical Findings

- Red (scleral injection) or cloudy (corneal edema, aqueous flare) eye of variable duration
- Ocular pain (squinting, tearing, rubbing eye)
- Decreased vision
- Previous trauma may indicate traumatic uveitis.
- Weight loss, lethargy, or decreased appetite may indicate a systemic cause.
- Bilateral uveitis supports systemic disease as the cause.

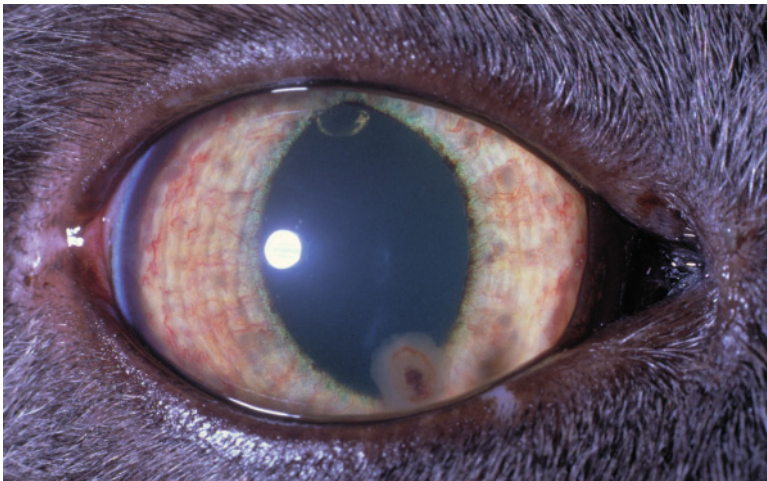


CLINICAL FEATURES

- Injection of conjunctival and scleral vessels.
- Aqueous flare—may be subtle and difficult to detect or severe causing anterior chamber to appear cloudy.
- Corneal edema—may be subtle or severe.
- Inflammatory cells may or may not be detected as hypopyon (white cells settled out in anterior chamber) or keratic precipitates (white cells deposited on the corneal endothelium, Figure 6.1).

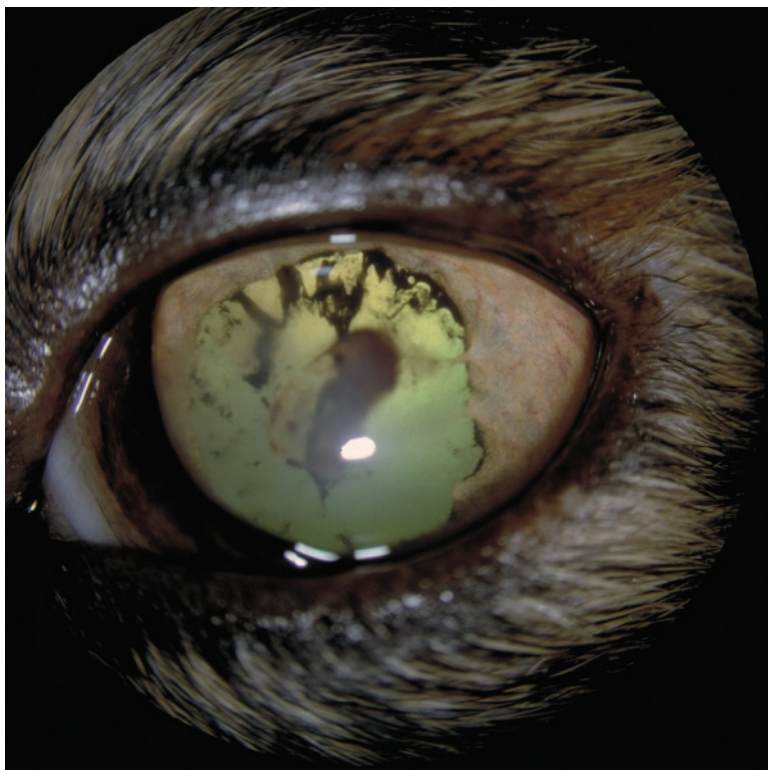


■ **Figure 6.1** Dog with chronic anterior uveitis, as indicated by the extensive corneal neovascularization. The corneal endothelium has numerous keratic precipitates causing the intraocular structures to be partially obscured.



■ **Figure 6.2** Cat with anterior uveitis. The pupil is misshapen (dyscoria) due to extensive posterior synechia. A fibrin clot is in the central pupil and pigment from the posterior iris pigmented epithelium has been deposited onto the lens capsule.

- Fibrin or blood clots in anterior chamber
- Miosis is seen primarily when acute, pupil is often mid-range.
- Iris swelling and vessel dilation—most obvious in light-colored eyes (Figure 6.2).
- Posterior synechia (adhesion of iris to lens capsule)—causes abnormal pupil shape, is seen in chronic cases and may be minimal or extensive (Figure 6.3).



■ **Figure 6.3** Cat with anterior uveitis. A small fibrin clot is partially overlying the pupil and iris ventrally. The iris is thickened and the iris vessels are injected. The circle in the dorsal pupil is a reflection.

- Iris bombé—accumulation of aqueous humor behind the iris causing it to billow forward, due to extensive posterior synechia preventing aqueous humor from entering the anterior chamber through the pupil.
- Decreases IOP unless aqueous humor outflow is obstructed, IOP can then be in normal range or elevated.
- If systemic disease is the cause of uveitis, related clinical signs may be detected.



DIFFERENTIAL DIAGNOSIS

- Conjunctivitis—injection of conjunctival vessels only, ocular discharge, no intraocular changes associated with anterior uveitis, normal IOP, pain usually mild and relieved with topical anesthetic
- Episcleritis/scleritis—conjunctival and scleral vessel injection, perilimbal corneal edema, sclera may be thickened, IOP and intraocular examination normal unless causing anterior uveitis
- Glaucoma—elevated IOP, dilated pupil common, globe may be enlarged (buphthalmos), and cornea may have stria

- Any condition that causes injection of the conjunctival or scleral vessels (e.g., keratitis, Horner's syndrome)



DIAGNOSTICS

- Ocular examination including corneal fluorescein staining and IOP measurement.
- Systemic disease—general physical examination, CBC, serum chemistries, urinalysis. Further testing (serology, microbiology, imaging studies) is done based on the results of physical examination and initial lab work.
- Ocular ultrasound is indicated when primary ocular disease is suspected or identified and intraocular examination is not possible due to opacification.
- Examination of aqueous or vitreous humor may be required for diagnosis; ocular fluids can be used for cytology, culture and sensitivity, polymerase chain reaction, and antibody content.

Pathologic Findings

- Cornea—edema; neovascularization (if chronic); keratic precipitates (aggregates of WBCs on corneal endothelium)
- Anterior chamber—RBCs, WBCs, and fibrin
- Iris—WBC infiltration (cell type dependent on etiology); adhesions of iris to lens (posterior synechia); adhesions of iris to cornea (anterior synechia); preiridal fibrovascular membrane (if chronic)
- Ciliary body—WBC infiltration similar to iris
- Lens—pigment migration on capsule; posterior synechia; cataract (if chronic)



THERAPEUTICS

- Treatment goals for anterior uveitis
 - Specific therapy for identified cause (treat corneal ulcer, infectious disease, neoplasia, luxated lens, etc.)
 - Nonspecific therapy for all cases of anterior uveitis—stop inflammation, prevent or control complications caused by inflammation (e.g., posterior synechia, glaucoma), and relieve pain.

Drug(s) of Choice

- Glucocorticoids
 - Topical
 - Prednisolone acetate 1% suspension every 1 to 12 hours
 - Dexamethasone 0.1% solution, 0.05% ointment every 1 to 12 hours
 - Frequency depends on severity of inflammation.
 - Taper medication as inflammation resolves.

- Subconjunctival injection
 - Methylprednisolone acetate 4 mg in each eye
 - Betamethasone 0.75 mg in each eye
 - Triamcinolone 4 mg in each eye
 - Rarely used to treat anterior uveitis
 - Used as a one-time injection in severe cases followed by topical therapy
 - Do not use in cats due to potential of concurrent FHV-1 infection
- Systemic
 - Prednisolone 5-mg tablet, prednisone 5-mg or 20-mg tablet, 0.5 to 2.2 mg/kg PO every 12 to 24 hours
 - Higher dosages for initial therapy of severe inflammation
 - Only used when systemic infectious causes have been ruled out
 - Taper medication as inflammation resolved
- Nonsteroidal anti-inflammatory drugs
 - Topical solutions
 - Diclofenac 0.1% every 6 to 12 hours
 - Flurbiprofen 0.03% every 6 to 12 hours
 - Suprofen 1% every 6 to 12 hours
 - Ketorolac 0.5% every 6 to 12 hours
 - Frequency depends on severity of inflammation
 - Systemic
 - Aspirin 80-mg tablet: 10 mg/kg every 12 hours; 10 to 20 mg/kg every 48 to 72 hours PO
 - Ketoprofen 12.5-mg tablet: ≤ 2 mg/kg PO once, ≤ 1 mg/kg every 24 hours
 - Meloxicam 1.5 mg/ml: 0.2 mg/kg PO initially, followed by 0.1 mg/kg PO (in food) once daily; 0.2 mg/kg PO initially, followed by 0.1 mg/kg PO (in food) every 24 hours for 2 days, then 0.25 mg/kg two to three times a week
 - Carprofen 25-mg, 75-mg, or 100-mg tablet: 2.2 mg/kg PO every 12 to 24 hours
 - Deracoxib 25-mg or 100-mg tablet: 1 to 2 mg/kg PO every 24 hours or 3 to 4 mg/kg PO every 24 hours (not to exceed 7 days at this dose)
- Topical mydriatic/cycloplegic
 - Atropine sulfate 1% solution and ointment: every 8 to 24 hours
 - Dilates pupil to prevent posterior synechia
 - Relieves ciliary muscle spasm to decrease pain
 - Frequency of administration depends on severity of inflammation.
 - Should be used judiciously to effect

Precautions/Interactions

- Topical and subconjunctival glucocorticoids are contraindicated in the presence of a corneal ulcer.
- Glucocorticoids used for subconjunctival injection are in a slow release vehicle, effects last up to 3 weeks.

- Methylprednisolone acetate may result in a subconjunctival inflammatory plaque that causes discomfort.
- Topical atropine can significantly reduce tear production.
- Continuous dilation of the pupil with atropine may obstruct aqueous humor outflow and contribute to development of secondary glaucoma.
- Use of systemic NSAIDs in cats has been associated with potentially serious side effects.
- Avoid treating with drugs that constrict the pupil (pilocarpine, latanoprost, demecarium bromide).



COMMENTS

Client Education

- The use of topical steroids is contraindicated if a corneal ulcer develops. Prevent self-trauma with a protective collar if necessary.
- Frequent follow up examinations are essential if inflammation is moderate to severe because secondary glaucoma is common.
- Further client education based on identified underlying cause.

Patient Monitoring

- Recheck in 1 to 7 days depending on severity.
- Monitor IOP—IOP because it will increase with decreased inflammation; if IOP increases with static or worsening inflammation this indicates aqueous outflow obstruction and impending glaucoma.
- Frequency of subsequent rechecks is dependent upon response to therapy.

Prevention/Avoidance

- Inadequate control of inflammation due to undertreating or discontinuing NSAIDs too soon or too rapidly may lead to recurrent or chronic uveitis.
- Whenever possible, the cause of uveitis should be identified and eliminated to prevent recurrence.

Possible Complications

- Posterior synechia causing abnormal pupil shape (dyscoria)
- Secondary glaucoma is common.
- Secondary cataract formation
- Retinal detachment
- Lens luxation
- Systemic complications are dependent on underlying systemic disease.

Expected Course and Prognosis

- Ocular outcome varies depending on severity of and ability to control inflammation and secondary glaucoma (if present).
- Systemic outcome varies depending on disease process.

Synonyms

- Iridocyclitis
- Iritis

Abbreviations

- CAV: caveolin
- CBC: complete blood count
- FeLV: feline leukemia virus
- FHV: feline herpes virus
- FIP: feline infectious peritonitis
- FIV: feline immunodeficiency virus
- IOP: intraocular pressure
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- RBC: red blood cell
- WBC: white blood cell

Suggested Reading

- Davidson, MG, Nasisse, MP, English ,RV, et al. Feline anterior uveitis: A study of 53 cases. *J Am Anim Hosp Assoc* 1991;27(1):77–83.
- Giuilano, EA. Nonsteroidal anti-inflammatory drugs in veterinary ophthalmology. *Vet Clin North Am Small Anim Pract* 2004;34:707–723.
- Martin, CL, Stiles, J. Ocular infections. In Greene, CE, ed., *Infectious Diseases of the Dog and Cat*, pp. 658–671. Philadelphia: WB Saunders, 1998.
- Massa, KL, Gilger, BC, Miller, TL, and Davidson, MG. Causes of uveitis in dogs: 102 cases (1989–2000). *Vet Ophthal* 2002;5(2):93–98.
- Wilkie, DA. Control of ocular inflammation. *Vet Clin North Am Small Anim Pract* 1990;20:693–713.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Ian P. Herring

Anticoagulant Rodenticide Toxicity



DEFINITION/OVERVIEW

- Ingestion of anticoagulant rodenticide compounds results in a depletion of vitamin K and functional vitamin K-dependent coagulation factors and causes an acquired coagulopathy.

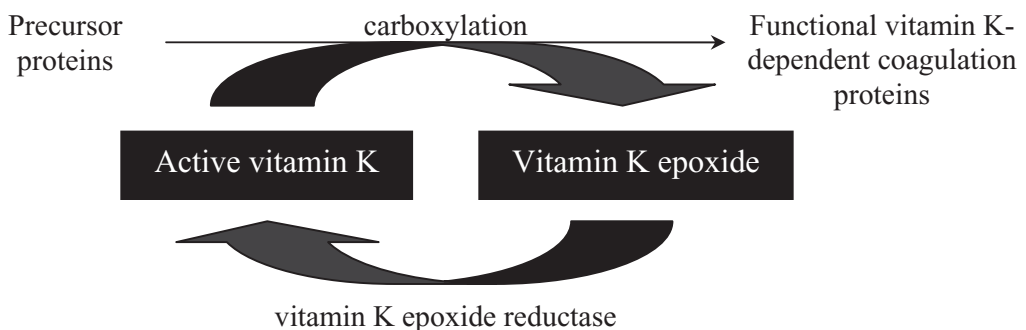


ETIOLOGY/PATHOPHYSIOLOGY

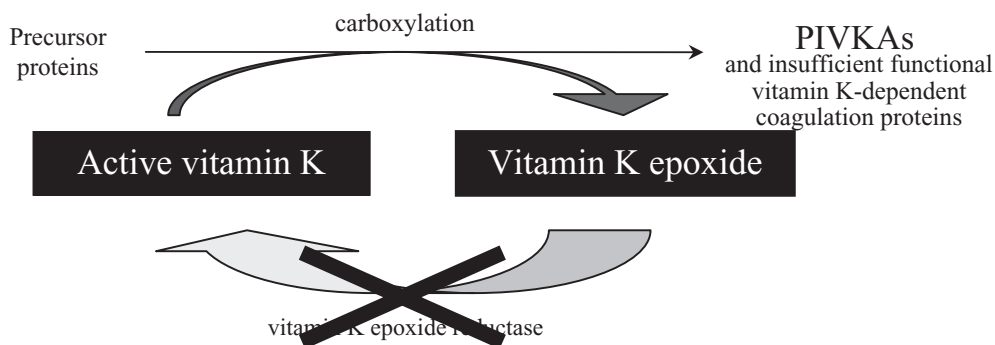
- Vitamin K, a fat-soluble vitamin, is a crucial cofactor for hepatic posttranslational carboxylation of coagulation factors II, VII, IX, and X (and protein C and protein S) (Figure 7.1).
- Anticoagulant rodenticide ingestion inhibits the hepatic enzyme, vitamin K epoxide reductase, and prevents the recycling of the vitamin K metabolite, vitamin K epoxide, back to its functional form (Figure 7.2).
- Once hepatic vitamin K stores are depleted, production of functional vitamin K-dependent coagulation proteins ceases and causes the formation of PIVKAs.
- PIVKAs are incapable of chelating calcium and therefore are unable to successfully partake in secondary hemostasis (soluble factor coagulation cascade).

Systems Affected

- Cardiovascular—hemopericardium, subepicardial hemorrhage
- Gastrointestinal—sublingual or gastric hemorrhage, hemoabdomen



■ **Figure 7.1** Normal coagulation factor synthesis.



■ **Figure 7.2** Proteins induced by vitamin K antagonists or absence (PIVKAs) formation in the presence of an anticoagulant rodenticide.

- Hemic/Lymphatic/Immune—active coagulation factor deficiency, anemia, hypoproteinemia
- Musculoskeletal—hemarthrosis, lameness
- Nervous—intracranial hemorrhage, seizures, paresis, paralysis
- Respiratory—hemothorax, parenchymal hemorrhage
- Skin/Exocrine—SQ hemorrhage



SIGNALMENT/HISTORY

- No specific signalment, although intact animals may be more likely to roam and be accidentally or maliciously exposed to toxins.

Risk Factors/Causes

- The presence of vitamin K antagonist rodenticides in the immediate environment.

Historical Findings

- May reveal possible exposure to or ingestion of anticoagulant rodenticides
- Ingestion of an animal that consumed anticoagulant rodenticide (relay toxicosis)
- Vomit or feces with green- or turquoise-colored granules in it
- Respiratory difficulty or hemorrhage
- Tolerance of previous surgery or trauma without evidence of clinical bleeding



CLINICAL FEATURES

- Clinical features are similar for dogs and cats.
- Clinically asymptomatic if ingestion occurred <48 hours previously.
- Clinical signs associated with deep tissue hemorrhage (hemoptysis, hemothorax, hemoabdomen, hemarthrosis, intracranial, pericardial, sublingual or subcutaneous

hemorrhage) most frequently develop between 2 and 6 days following consumption.

- In the acutely bleeding patient, hypoproteinemia will generally develop prior to the anemia; anemia may develop simultaneously or before hypoproteinemia in the face of slow and sustained hemorrhage.



DIFFERENTIAL DIAGNOSIS

- Similar between dogs and cats, with the exception of variations in inherited coagulation factor deficiencies
- Hepatic failure
- Disseminated intravascular coagulation
- Dilutional coagulopathy
- Congenital factor deficiency
- Massive heparin overdose
- Spurious results (underfilling tube, polycythemia, delay in performing assay)
- Absolute vitamin K deficiency (malnourished patients receiving broad-spectrum antibiotic therapy, posthepatic biliary obstruction, or exocrine pancreatic insufficiency or intestinal malabsorption)
- Abnormal gamma-glutamyl carboxylase enzyme (Devon Rex)



DIAGNOSTICS

- Diagnosis is often made with a history, clinical presentation, or coagulation profile that supports the diagnosis, all in the face of a rapid response to vitamin K₁ therapy.
- Following ingestion, an anticoagulant effect is initially manifested as a prolonged PIVKA test (12–24 hours), then followed by a prolonged PT (24–36 hours); this initial anticoagulant effect is due solely to factor VII deficiency, which has the shortest half-life (generally 6 hours).
- Prolongation of the aPTT follows, after an additional 24 to 48 hours (48–96 hours post-ingestion).
- Prolongation of the ACT is the last coagulation test to be abnormal, due to its lack of sensitivity to coagulation factor deficiency.
- A patient with spontaneous, active hemorrhage will have prolongation of PT, aPTT, ACT, and PIVKA test.
- Rarely is analysis of plasma or hepatic tissue needed to confirm the presence of compatible toxin.

Pathological Findings

- Presence of nonclotting blood found on aspiration of body cavity or swelling.
- Hemorrhage in the airways; uncommonly hemorrhage from mucosal surfaces.



THERAPEUTICS

- Treatment depends on timing of ingestion and the urgency of the clinical presentation.

Drug(s) of Choice

- Emesis is induced if ingestion occurred within previous 2 hours.
- Activated charcoal administration is ideal if ingestion occurred within previous 2 hours; this however may delay efficacy of orally administered vitamin K₁.
- Vitamin K₁: 2.5 to 5 mg/kg per day PO for up to 6 weeks (dependent on agent ingested) is indicated for all patients with confirmed or even suspected ingestion; oral administration is generally more rapidly effective (<12 hours) than SQ (12–24 hours) and safer than intravenous dosing (risk of anaphylaxis).
- Vitamin K₁ therapy alone is usually sufficient to reverse the anticoagulant effect in patients with prolonged PT without hemorrhage.
- In more urgent cases (i.e., presence of hemorrhage) plasma (fresh frozen or frozen) 10 to 15 ml/kg or whole blood (fresh or stored) up to 20 ml/kg are administered, concurrently with oral or SQ vitamin K₁ to promptly (although temporarily) reverse anticoagulation.
- Cautious intravenous fluid administration to reverse shock, while minimizing exacerbation of further hemorrhage with unnecessary or excessive increases in blood pressure.
- Oxygen therapy if hypoxemia is present or in an attempt to ease respiratory distress; avoid nasal oxygen cannulation due to risk of inducing hemorrhage/epistaxis.

Precautions/Interactions

- Orally administered vitamin K may be insufficiently absorbed if concomitant intestinal malabsorption or extrahepatic biliary obstruction is present; hepatic dysfunction tempers the response to vitamin K₁ therapy.
- Allergic reactions (i.e., urticaria, angioneurotic edema) may occur with SQ vitamin K₁ therapy, whereas anaphylaxis is a concern with intravenous administration.
- Vitamin K₁ administered IM may result in hematoma formation and therefore is contraindicated.
- Small-gauge needles should be used for SQ administration of vitamin K₁ (or any other parenteral medications) in several different sites to expedite absorption.
- Gastroenteric lavage is not indicated due to rapidly reversible nature of toxicity.

Alternative Drugs

- Oxyglobin® may be utilized to temporarily improve oxygen-carrying capacity if blood products are not readily available, providing time for vitamin K₁ therapy to become effective.

Diet

- Administration of vitamin K₁ with a high fat meal (i.e., canned food) improves bioavailability.

Activity

- With complicated toxicity, activity should be limited to avoid exacerbation of hemorrhage.

Surgical Considerations

- Thoracocentesis may be indicated if the development of a hemothorax sufficiently compromises respiration.
- Preferably avoid unnecessary procedures until coagulation ability has normalized.



COMMENTS

Client Education

- Early in the course of therapy provide extra bedding to prevent pressure-induced hemorrhage and avoid restraint with a collar to limit risk of ocular or intracranial hemorrhage.
- Herbal supplements, notably garlic, ginkgo, and ginseng, may exacerbate hemorrhagic tendencies.
- Vitamin E supplementation interferes with vitamin K-dependent coagulation.
- Toxins may be excreted in the milk of lactating patients.

Patient Monitoring

- For uncomplicated and complicated toxicity, monitor PT 48 to 96 hours after discontinuation of vitamin K₁ therapy to prove therapy has been administered for a sufficient duration; if prolonged, reinstitute vitamin K₁ therapy for 1 to 3 more weeks and repeat PT as previously instructed.
- For complicated toxicity, monitor for clinical signs associated with hemorrhage (i.e., tachycardia, pale mucous membranes, increase in respiratory rate, evidence of pleural space disease, hypotension, collapse, etc.).

Prevention/Avoidance

- Do not allow further access to toxin.
- Preferably avoid elective, invasive procedures until coagulation deficits have normalized.
- Nursing puppies or kittens should be changed to hand rearing and possibly supplemented with vitamin K₁ therapy.

Possible Complications

- Fatal hemorrhage (i.e., intracranial, myocardial, pericardial, intrapulmonary)

Expected Course and Prognosis

- In the absence of fatal hemorrhage, early and aggressive therapy should provide complete recovery with rapid cessation of hemorrhage and eventually normalization of coagulation tests (PT, aPTT, and ACT).

Abbreviations

- ACT: activated clotting time
- aPTT: activated partial thromboplastin time
- DIC: disseminated intravascular coagulation
- PC: protein C
- PIVKA: proteins induced by vitamin K antagonists or absence
- PO: by mouth
- PT: prothrombin time
- SQ: subcutaneously

Suggested Reading

Bahri, LE. Vitamin K. *Compend Contin Educ Pract Vet* 2005;27(1):43–46.

Prater, RM. Acquired coagulopathy I: Avitaminosis K. In: Feldman, BF, Zinkl, JG, Jain, NC, *Schalm's Veterinary Hematology*, 5th ed., pp. 556–559. Baltimore: Williams & Wilkins, 2000.

Smith, JW, Day, TK, and Mackin, A. Diagnosing bleeding disorders. *Compend Contin Educ Pract Vet* 2005;27(11):828–843.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Gary J. Kociba

Arterial Thromboembolism (ATE)



DEFINITION/OVERVIEW

- ATE results from a thrombus or blood clot that is dislodged within the aorta, causing severe ischemia to the tissues served by that segment of aorta. It is one of the most devastating complications associated with myocardial diseases in cats.



ETIOLOGY/PATHOPHYSIOLOGY

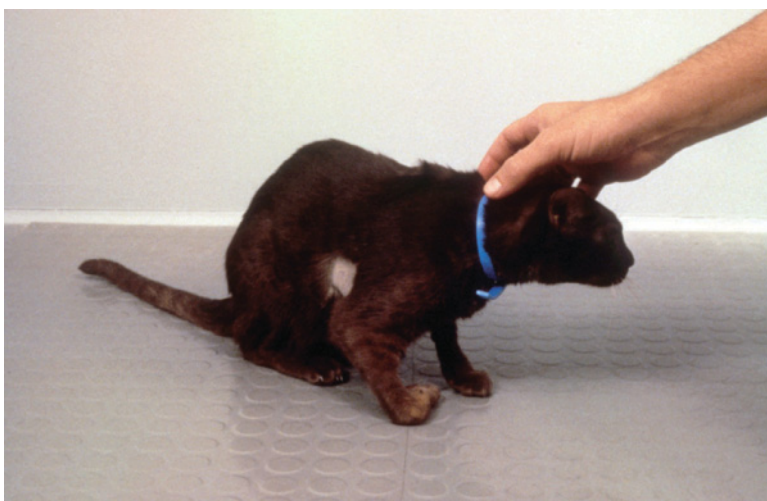
- ATE is most commonly associated with myocardial disease in cats, including hypertrophic, restrictive, and dilated cardiomyopathy.
- Although the exact etiology of ATE has not been determined, it is theorized that abnormal blood flow (stasis) and a hypercoagulable state contribute to the formation of the thrombus within the left atrium. The blood clot is then embolized distally to the aorta.
- The most common site of embolization is the caudal aortic trifurcation causing ischemic injury to both hind legs (Figure 8.1).
- Other less common sites include the front leg (Figure 8.2), kidneys, gastrointestinal tract, or cerebrum.
- Although ATE is a well-recognized complication of myocardial disease in cats, the exact prevalence of ATE is not known in the general population of cats. In one study of cats with hypertrophic cardiomyopathy, approximately 17 percent presented with signs of ATE.
- Although >95 percent of ATE in cats are associated with advanced feline heart disease, another associated condition is neoplasia, typically pulmonary carcinoma.
- ATE rarely occurs in dogs. ATE in dogs typically is associated with neoplasia, sepsis, Cushing's disease, protein-losing nephropathy, or other hypercoagulable states. Severe heart disease is not often associated with ATE in the dog.

Systems Affected

- Cardiovascular—the majority of affected cats have advanced heart disease and experience left-sided heart failure.
- Nervous/musculoskeletal—severe ischemia to the muscles and nerves served by the segment of occluded aorta causes variable pain and paresis. Gait abnormalities or paralysis results in the leg or legs involved.



■ **Figure 8.1** Clot in the hind limb of a cat after arterial thromboembolism. Note the extensor rigidity of the affected limb.



■ **Figure 8.2** Clot in the forelimb of a cat with arterial thromboembolism. Note the conscious proprioceptive deficits.



SIGNALMENT/HISTORY

- Typically middle-aged to older male mixed breed cat.
- Median age is typically 7 to 10 years (Range 1–20 years).
- Males are more commonly affected than females (2:1).
- The most common breed affected is the mixed breed cat. However, certain breeds have been overrepresented, such as Ragdolls, typically mirroring breeds that are prone to cardiomyopathies.

Risk Factors/Causes

- Although clear risk factors have not been defined, it is theorized that an enlarged left atrium or spontaneous echo contrast of the red blood cells or “smoke” observed on an echocardiographic examination may be risk factors.

Historical Findings

- Acute onset paralysis/paresis and pain are the most common owner complaints.
- Lameness or other gait abnormality may be seen.
- Tachypnea or respiratory distress is common.
- Vocalization and anxiety are common.



CLINICAL FEATURES

- Usually paraparesis or paralysis of the rear legs. Typically both rear legs are affected equally but occasionally one leg is worse than the other. Less commonly, monoparesis of a front leg.
- Pain upon palpation of the affected legs. Gastrocnemius muscle often becomes firm several hours after embolization.
- Absent or diminished femoral pulses
- Cyanotic or pale nail beds and footpads (Figure 8.3)
- Affected limbs will be cooler than unaffected limbs upon palpation.



■ **Figure 8.3** Differential cyanosis. Note the cyanotic discoloration of the footpads in the limb affected by the clot.

- Cardiac murmur or gallop sound may or may not be present. Despite the typical presence of severe heart disease in cats, often times a murmur or gallop may not be heard.
- Tachypnea or respiratory distress, sometimes with open mouth breathing, is often present either due to pain associated with the ischemic leg injury or due to concurrent congestive heart failure.
- Cardiac dysrhythmias may also be present. Dysrhythmias are more common during treatment and are often associated with reperfusion injury and hyperkalemia.
- Hypothermia is common in cats with ATE and is often associated with poor systemic perfusion and worse prognosis.



DIFFERENTIAL DIAGNOSIS

- Hind limb paresis secondary to other causes such as spinal neoplasia, trauma, myelitis, fibrocartilaginous infarction, or intervertebral disk protrusion.



DIAGNOSTICS

- Typically, the diagnosis of ATE is made by physical exam alone. Many cats are in distress and empiric treatment is often initiated *prior to* diagnostic testing. In the cat, further diagnostic evaluation is helpful to better evaluate the severity and nature of the associated cardiac disease as well as systemic effects of the ATE. This information may be helpful for prognosis and treatment.
- In the dog, diagnostic evaluation is helpful to better understand the associated disease causing the hypercoagulable state.

Complete Blood Count/Biochemistry Panel/Urinalysis

Common abnormalities include:

- Elevated CPK, AST, ALT
- Stress hyperglycemia
- Azotemia with elevated BUN and creatinine as a result of possible low effective circulating volume or renal emboli
- Electrolyte abnormalities are common (i.e., hyponatremia, hyperkalemia, hypocalcemia and hyperphosphatemia) and are likely associated with poor renal perfusion and reperfusion injury.
- CBC and urinalysis changes are nonspecific.
- In the dog, a protein-to-creatinine ratio is advised if proteinuria is identified.

Other Laboratory Tests

- Routine coagulation profile typically does not reveal significant abnormalities.
- In the dog, D-dimers are typically markedly elevated.

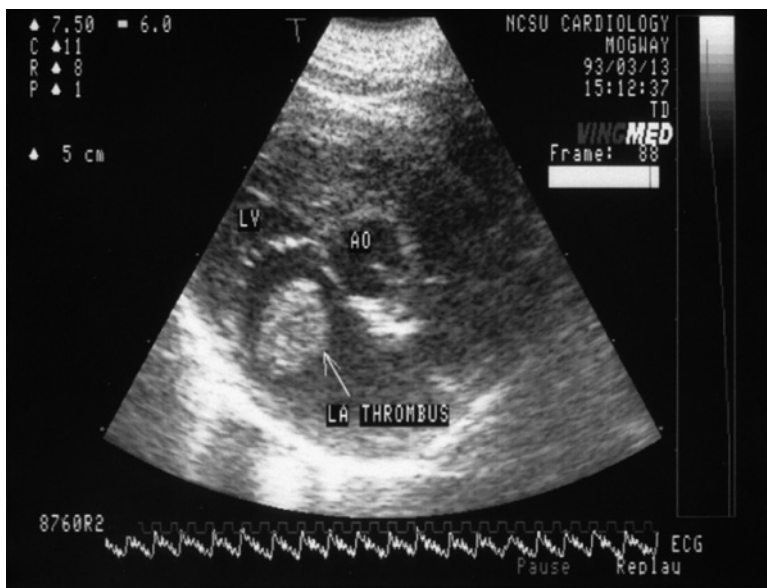
- Baseline coagulation profile may be helpful to titrate heparin and possibly warfarin dosages.
- Thyroid hormone should be measured in cats over 7 years of age.

Thoracic Radiography

- Cardiomegaly is common and radiographic signs of congestive heart failure (i.e., pulmonary edema and/or pleural effusion) is seen in approximately 50–66 percent of cats.
- The presence of a pulmonary mass in the absence of heart disease in a cat with ATE is concerning for pulmonary carcinoma associated embolus.

Echocardiography

- The majority of cats will have hypertrophic cardiomyopathy characterized by left ventricular hypertrophy, nondilated left ventricular lumen, and enlarged left atrium.
- Other types of heart disease are also possible such as unclassified, restrictive, or dilated cardiomyopathy and thyrotoxic heart disease.
- Regardless of the type of myocardial disease present, the majority (>50%) have severe left atrial enlargement, (i.e., a left atrial to aortic ratio of ≥ 2.0).
- Occasionally, a left atrial thrombus or spontaneous echo contrast of the red blood cells (smoke) may be seen (Figure 8.4).



■ **Figure 8.4** Echocardiographic image of an enlarged left atrium that contains a thrombus.

Abdominal Ultrasonography

- An experienced sonographer may be able to identify the thrombus in the caudal aorta. However, this imaging modality typically is not necessary to reach a diagnosis, especially in a cat.
- Abdominal ultrasound may be more useful in the dog to both identify the thrombus and look for associated diseases.

Computed Tomography Scan

- As with abdominal sonography, a multidetector CT scan is not necessary for diagnosis in a cat but could be helpful in a dog to reach a diagnosis, evaluate the extend of the thrombus and look for associated diseases.

Pathologic Findings

- Thrombus typically is identified at the caudal aortic trifurcation.
- Occasionally, a left atrial thrombus is seen.
- Emboli of the kidneys, gastrointestinal tract, cerebrum, and other organs also may be observed.



THERAPEUTICS

The main objectives of treatment are threefold:

- First, immediate treatment of the pain associated with ischemic injury of the legs, typically with injectable opioids.
- Treatment directed at resolving the actual thrombus with anticoagulants or possibly thrombolytic agents.
- Treatment of the cat's heart disease and possible congestive heart failure.

Drug(s) of Choice

Pain Management

Once the diagnosis is reached, addressing the pain and distress associated with ATE is an immediate concern. If possible, intravenous opioid administration is preferred because of its rapid onset of action, bioavailability, and safety profile.

- In the cat, buprenorphine at 0.005 to 0.01 mg/kg IV every 6 to 8 hours as needed is an initial good choice. Buprenorphine can also be given in the cheek pouch or SQ if intravenous access is not obtained.
- Fentanyl (2–3 µg/kg intravenous bolus, then 1–5 µg/kg per hour IV CRI).
- Hydromorphone (0.025–0.1 mg/kg IV or SQ every 4–6 hours)
- Butorphanol (0.05–0.3 mg/kg IV or SQ every 2–6 hours as needed) has fewer analgesic effects than buprenorphine but is a good sedative. If no other opioids are available or if the cat's pain is assessed as mild, then butorphanol is a reasonable choice.

- Cautious use of low dose acepromazine (0.01 mg/kg IV or SQ every 8–12 hours as need) may be helpful for additional sedation and vasodilation. Avoid acepromazine in patients with hypotension or hypothermia because of concerns of worsening systemic perfusion.

Antithrombotic Management

- Thrombolytic therapy with drugs such as streptokinase and tissue plasminogen activator is used extensively in human and infrequently in cats. These drugs are expensive, carry a significant risk for bleeding complications, need to be administered within a few hours of ATE, and have not demonstrated significant therapeutic benefit over conservative management in veterinary medicine. Thus, they are rarely used in general practice settings.
- Unfractionated heparin is the preferred drug in most clinical practices. Heparin actually has no effect on the established clot; however, it prevents further activation of the coagulation cascade and allows the body's endogenous fibrinolytic system to break down the clot. The initial dose typically is given IV then followed with subcutaneous administrations every 6 to 8 hours. The initial intravenous dose is 100 to 200 units/kg and the subsequent subcutaneous dose is 200 to 300 units/kg. Alternatively, an intravenous CRI of heparin at 600 units/kg per day could be used after the initial bolus. The dose is then ideally titrated to prolong the aPTT approximately twofold.
- In addition to heparin, the concurrent use of an antiplatelet agent is also advised. The two antiplatelet options are aspirin (5–81 mg PO every 3 days) or clopidogrel (18.75 mg (1/4 of a 75-mg tablet) PO every 24 hours).
 - The higher dose of aspirin may be associated with more gastrointestinal adverse effects.
 - The theoretical benefit of clopidogrel is less gastrointestinal adverse effects and possible enhanced efficacy.
- Once signs of clinical improvement are seen, heparin therapy is gradually weaned over 1 to 2 days and long-term therapy is continued.

Dog

- Acute antithrombotic management considerations are similar in the dog.
- The dose of heparin in the dog is generally the same as in the cat. The doses of the antiplatelet agents are different.
 - Canine aspirin dose is 0.5 to 1 mg/kg PO every 24 hours.
 - The dose of clopidogrel dose in the dog is approximately 2 mg/kg PO every 24 hours.
 - A higher loading dose of 10 to 11 mg/kg could be used on the first day if active clot is associated with significant ischemia.

Long-Term Therapy

- Recommendations for long-term anticoagulation are variable because no one treatment modality has shown clear benefit over another.

- Factors involved in deciding which long-term therapy to use include expense, ease of oral as opposed to subcutaneous administration, need for reevaluation, and monitoring.
- Commonly used long-term anticoagulant therapies include aspirin, clopidogrel, or a low molecular weight heparin. None of these treatment options require monitoring for therapeutic efficacy.
- Aspirin (5 to 81 mg every 3 days) is the least expensive option and is dosed every 3 days but carries a higher risk of gastrointestinal and renal adverse effects.
- Clopidogrel (18.75 mg every 24 hours) is moderately expensive and is dosed daily but may have enhanced long-term efficacy.
- Low molecular weight heparins have also been used in the long-term management of cats surviving an ATE.
 - Dalteparin (100–200 unit/kg SQ every 12–24 hours) or enoxaparin (1.5 mg/kg SQ every 12–24 hours) are two commonly used low molecular weight heparins.
 - The disadvantages of these medications are expense, subcutaneous administration, and controversy over the therapeutically efficacious dose in the cat.

Congestive Heart Failure Management

- Oxygen-rich environment
- Furosemide (1–4 mg/kg as needed, not to exceed 12 mg/kg per day) IV or SQ should provide immediate relief of respiratory distress due to concurrent congestive heart failure.
- Other cardiac therapies such as enalapril, diltiazem, or pimobendan may also be indicated.

Precautions/Interactions

- Anticoagulant therapy with heparin, clopidogrel, or the thrombolytic drugs may cause severe bleeding complications.
- Reperfusion of severely ischemic legs may be associated with severe hyperkalemia. Death due to hyperkalemia and ischemia-reperfusion injury is a common cause of in-hospital mortality.
- Avoid a nonselective β -blocker such as propranolol as it may enhance peripheral vasoconstriction.

Alternative Drugs

- Warfarin, a vitamin K antagonist, is the anticoagulant most widely used in humans and could be considered if recurrent ATE.
 - The initial dose is 0.05 to 1 mg/kg PO every 24 hours. It should be overlapped with heparin therapy for 3 days. The dose is then adjusted to prolong the PT approximately two times its baseline value or to attain an INR of 2.0–4.0.
 - Warfarin has an unpredictable dose-to-response effect and is highly protein bound. Thus, frequent monitoring and titration of the dose are required. Warfarin also carries a more significant risk of bleeding.

Diet

- Initially, most cats are anorexic. Tempt these cats with any type of diet. It is important to keep these cats eating to avoid hepatic lipodosis. Appetite stimulants are often used. Naso-esophageal tube feedings may be indicated if more than 3 days of anorexia. Chronic dietary management usually involves sodium restriction.

Activity

- Activity should be restricted. The cat should be kept quiet, stress free and indoors only.

Surgical Considerations

- Surgical embolectomy typically is not recommended because these patients are high risks for surgery and anesthesia as a result of their heart disease.
- Rheolytic thrombectomy has recently been evaluated in the treatment of feline ATE with favorable treatment results but is not commonly available even at tertiary referral centers.



COMMENTS

- It should be emphasized that the finding of tachypnea, even open mouth breathing, upon initial examination should not presume congestive heart failure. Some cats may be tachypneic solely as a result of pain. If the tachypnea persists after appropriate analgesic therapy, or if physical examination (crackles) or radiographic findings are compatible with pulmonary edema, then furosemide therapy is indicated.
- Fluid therapy may be necessary in the initial stages if the cat is not in congestive heart failure.
- Initially, the affected legs should be minimally handled because reperfusion results; long-term, physical therapy (passive extension and flexion of the legs) may speed full recovery.
- No venipuncture should be performed on the affected legs.
- Initially, these cats may have difficulty posturing to urinate and may need to have their bladders expressed periodically to prevent overdistention of the bladder or urine scald.

Client Education

- Owners should be aware of the poor short- and long-term prognosis. Many cats will have advanced heart disease and are at risk for re-embolization. They will require lifelong medications, re-evaluations, and an indoor lifestyle if the cat survives to discharge.
- Typically, most cats that survive an initial episode will recover complete function to the legs; however, some neurologic or musculoskeletal deficits may persist.

Patient Monitoring

- Hourly to daily examination of the legs, femoral pulses, and respiratory rate should be performed to assess clinical response to therapy.
- Continuous ECG monitoring is helpful to identify hyperkalemia cardiac arrhythmias/conduction disturbances associated with severe reperfusion injury.
- aPTT can also be monitored once daily to titrate the heparin dose.
- Periodic evaluation of thoracic radiographs, electrolyte, and renal parameters are also helpful in evaluating response to therapy.

Prevention/Avoidance

- Because of the high rate of re-embolization (25 to 75 %) after surviving an initial episode, prevention with either chronic aspirin, clopidogrel or low molecular weight heparin is strongly recommended. See above for doses.

Possible Complications

- Death is unfortunately a common outcome either due to progression of disease or complication of therapy.
- Bleeding complications may arise with the anticoagulant therapy.
- Life-threatening hyperkalemia and arrhythmias due to reperfusion injury is a complication of therapy.
- Permanent neurological deficits or muscular abnormalities in the hind limbs may arise in some cats (~15 percent) with severe and prolonged ischemia.
- If a cat survives initial episode of ATE, recurrence of ATE and congestive heart failure is common.

Expected Course and Prognosis

- Both short-term and long-term prognosis are generally poor. Most cats (>50 percent) are euthanized or die during their initial ATE event regardless of therapy utilized.
- Admitting rectal temperature of >99°F, fast heart rate, only one limb affected and presence of motor function are all associated with better short-term prognosis.
- Concurrent congestive heart failure is associated with a worse long-term prognosis. In one study, cats with concurrent congestive heart failure had a median survival time of 77 days versus those without congestive heart failure of 233 days.
- Refractory congestive heart failure or recurrence of ATE is typical terminal issues if a cat survives an initial ATE event.
- Expected course of recovery is generally days but can be weeks for return of function to the legs.
- Most cats that survive an initial episode will recover completely but approximately 15 percent of cats may suffer permanent neuromuscular deficits or ischemic injuries such as loss of digits or tip of tail.

Synonyms

- Saddle thrombus

Abbreviations

- ALT: alanine transaminase
- aPTT: activated partial thromboplastin time
- AST: aspartate aminotransferase
- ATE: arterial thromboembolism
- BUN: blood urea nitrogen
- CBC: complete blood count
- CPK: creatine phosphokinase
- CRI: constant rate infusion
- CT: computed tomography
- ECG: electrocardiogram
- INR: international normalized ratio
- IV: intravenously
- PO: by mouth
- PT: prothrombin time
- SQ: subcutaneously

Suggested Reading

- Hogan, DF, Andrews, DA, Green, HW, Talbott, KK, Ward, MP, and Calloway, BM. Antiplatelet effects and pharmacodynamics of clopidogrel in cats. *J Am Vet Med Assoc* 2004;225:1406–1411.
- Rush, JE, Freeman, LM, Fenollosa, NK, and Brown, DJ. Population and survival characteristics of cats with hypertrophic cardiomyopathy: 260 cases (1990–1999). *J Am Vet Med Assoc* 2002;20: 202–207.
- Smith, SA, and Tobias, AH. Feline arterial thromboembolism: an update. *Vet Clin Small Anim* 2004;34:1245–1271.
- Smith, SA, Tobias, AH, Jacob, KA, Fine, DM, and Grumbles, PL. Arterial thromboembolism in cats: acute crisis in 127 cats (1992–2001) and long-term management with low-dose aspirin in 24 cases. *J Vet Intern Med* 2003;17:73–83.
- Schoeman, JP. Feline distal aortic thromboembolism: a review of 44 cases (1990–1998). *J Feline Med Surg* 1999;1:221–231.

Author: Terri DeFrancesco

Atrial Fibrillation and Atrial Flutter



DEFINITION/OVERVIEW

- Atrial fibrillation—rapid, irregularly irregular supraventricular rhythm.
- Two forms recognized: primary atrial fibrillation, an uncommon disease that occurs mostly in large dogs with no underlying cardiac disease, and secondary atrial fibrillation, which occurs in dogs and cats secondary to underlying cardiac disease.
- Atrial flutter is similar to atrial fibrillation, but the atrial rate is generally slower and is characterized by saw-toothed flutter waves in the baseline of the ECG. The ventricular response is generally rapid but may be regular or irregular.

Electocardiogram Features

Atrial Flutter

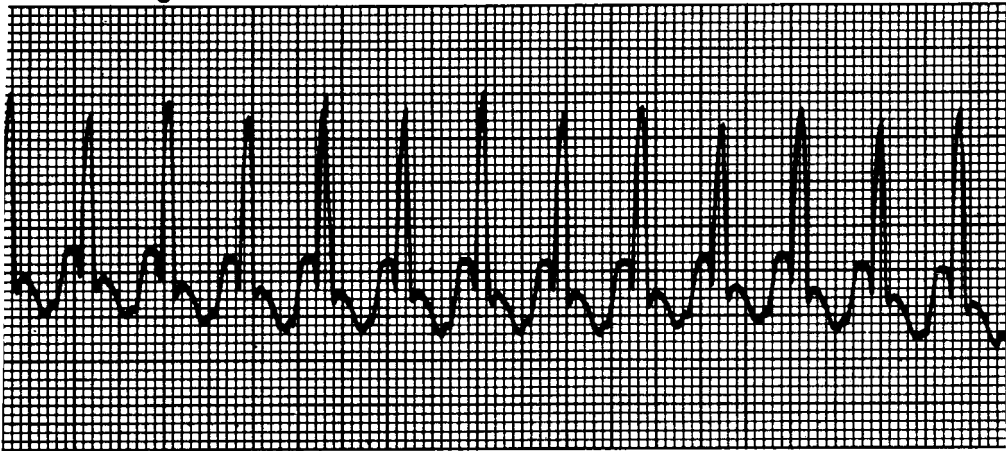
- Atrial rhythm usually regular; rate approximately 300 to 400 beats per minute
- P waves usually discerned as either discrete P waves or a “saw-toothed” baseline
- Ventricular rhythm and rate generally depend on the atrial rate and AV nodal conduction, but are generally regular or regularly irregular and rapid.
- Conduction pattern to the ventricles is variable—in some cases every other atrial depolarization produces a ventricular depolarization (2:1 conduction ratio), giving a regular ventricular rhythm; other times the conduction pattern appears random, giving an irregular ventricular rhythm that can mimic atrial fibrillation (Figure 9.1).

Secondary Atrial Fibrillation

- No P waves present—baseline may be flat or may have small irregular undulations (“f” waves); some undulations may look like P waves (Figure 9.2).
- Ventricular rate high—usually 180 to 240 beats per minute in dogs and >220 beats per minute in cats.
- Interval between QRS complexes is irregularly irregular; QRS complexes usually appear normal.

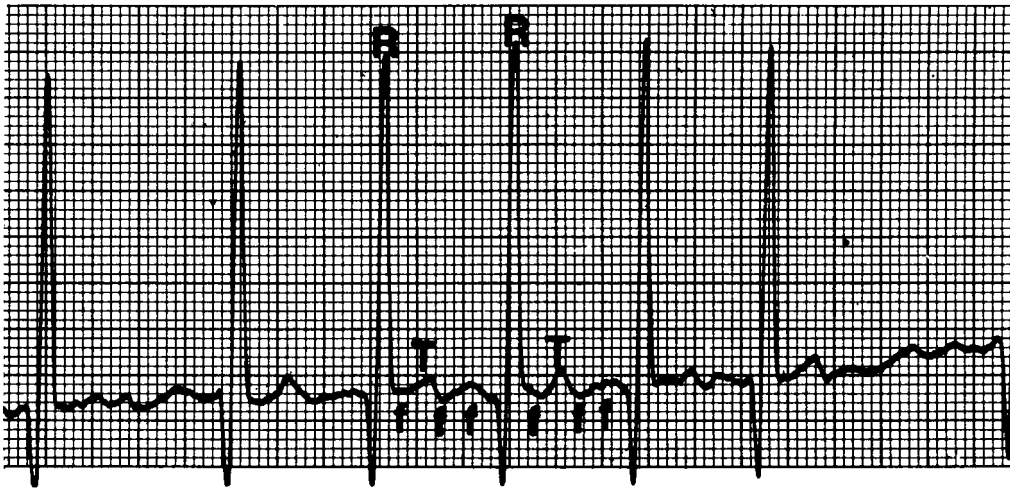
Primary Atrial Fibrillation

- Similar to secondary atrial fibrillation except ventricular rate usually in the normal range.



■ **Figure 9.1** Atrial flutter with 2:1 conduction at ventricular rate of 330/minute in a dog with an atrial septal defect. This supraventricular tachycardia was associated with a Wolff-Parkinson-White pattern.

From: Tilley, L.P. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Baltimore: Williams & Wilkins, 1992, with permission.



■ **Figure 9.2** "Coarse" atrial fibrillation in a dog with patent ductus arteriosus. The f waves are prominent.

From: Tilley, L.P. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Baltimore: Williams & Wilkins, 1992, with permission.



ETIOLOGY/PATHOPHYSIOLOGY

Risk Factors/Causes

- Heart disease
- Chronic valvular disease

- Cardiomyopathy
- Congenital heart disease
- Digoxin toxicity
- Idiopathic
- Ventricular pre-excitation (atrial flutter)

Atrial Fibrillation

- Caused by numerous small reentrant pathways creating a rapid (>500 depolarizations per minute) and disorganized depolarization pattern in the atria that results in cessation of atrial contraction.
- Depolarizations continuously bombard the AV nodal tissue, which acts as a filter and does not allow all depolarizations to conduct to the ventricles.
- Many atrial depolarizations activate only a part of the atria because the rapid rate renders portions of the atria refractory, and thus they cannot reach the AV junction.
- Other atrial impulses penetrate into the AV junctional tissue but are not robust enough to penetrate the entire length. Blocked impulses affect the conduction properties of the AV junctional tissue and alter conduction of subsequent electrical impulses; electrical impulses are conducted through the AV junction irregularly, producing an irregular ventricular rhythm.

Atrial Flutter

- Probably originates from one site of reentry that moves continuously throughout the atrial myocardium and frequently and regularly stimulates the AV node. When the atrial rate becomes sufficiently fast, the refractory period of the AV node exceeds the cycle length (P to P interval) of the SVT, and some atrial depolarizations are blocked from traversing the AV node (functional second-degree AV block).

Systems Affected

Cardiovascular

- Loss of atrial contraction may result in decreased stroke volume and cardiac output depending on heart rate.
- High heart rate may result in deterioration in myocardial function (tachycardia-induced myocardial failure).



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predispositions

- Large- and giant-breed dogs are more prone to primary atrial fibrillation.

General Comments

- Signs generally relate to the underlying disease process or CHF rather than the arrhythmia itself, but previously stable animals may decompensate.
- Patients with primary atrial fibrillation are generally asymptomatic but may demonstrate mild exercise intolerance.

Historical Findings

- Coughing/respiratory difficulty/tachypnea
- Exercise intolerance
- Rarely syncope
- Dogs with primary atrial fibrillation are typically asymptomatic.

Physical Examination Findings

- On auscultation, patients with atrial fibrillation have an erratic heart rhythm that sounds like “tennis shoes in a dryer” or “jungle drums.”
- First heart sound intensity in atrial fibrillation is variable; second heart sound only heard on beats with effective ejection, not on every beat
- Third heart sounds (gallop sounds) may be present.
- Patients with atrial fibrillation have pulse deficits and variable pulse quality.
- Signs of CHF often present (e.g., cough, respiratory distress, cyanosis)



DIFFERENTIAL DIAGNOSIS

- Frequent atrial (supraventricular) premature depolarizations
- SVT with AV block



DIAGNOSTICS

Imaging

- Echocardiography and radiography may characterize type and severity of the underlying cardiac disease; moderate to severe left atrial enlargement common.
- Typically normal in patients with primary atrial fibrillation, although mild left atrial enlargement may accompany the hemodynamic alterations imposed by the arrhythmia.

Pathologic Findings

- Depend on underlying cause



THERAPEUTICS

Drug(s) of Choice

- Digoxin, β -adrenergic blockers, and calcium channel blockers (diltiazem) are frequently used to slow conduction through the AV node; definition of an adequate heart rate response varies among clinicians, but in dogs is generally 140 to 160 beats per minute.

Dogs

- Digoxin—maintenance oral dose 0.005 to 0.01 mg/kg PO every 12 hours; to achieve a therapeutic serum concentration more rapidly, the maintenance dose can be doubled for the first day. If digoxin is administered alone and the heart rate remains high, check the digoxin level and adjust the dose to bring the level into the therapeutic range. If the heart rate remains high, consider adding a calcium channel blocker or a β -adrenergic blocker.
- Diltiazem—initially administered at a dose of 0.5 mg/kg PO every 8 hours, then titrated up to a maximum of 1.5 mg/kg PO every 8 hours or until an adequate response is obtained.
- Either high-dose oral quinidine or electrical cardioversion can be used to convert primary atrial fibrillation into sinus rhythm. Quinidine doses as high as 20 mg/kg PO every 2 hours can be used safely if monitored closely; doses lower than 12.5 mg/kg every 6 hours are generally ineffective.

Cats

- Diltiazem (1–2.5 mg/kg PO every 8 hours) or atenolol (6.25–12.5 mg PO every 12–24 hours) are the drugs of choice in most cats.
- If the heart rate is not sufficiently slowed with these drugs or if myocardial failure is present, digoxin (0.005 mg/kg PO every 24–48 hours) can be added.

Precautions/Interactions

- Calcium channel blockers and β -adrenergic blockers, both negative inotropes, should be used cautiously in animals with myocardial failure.
- Using high-dose oral quinidine for conversion into sinus rhythm carries a risk of quinidine toxicity (e.g., hypotension, weakness, ataxia, and seizures); administration of diazepam IV controls seizures; other signs abate within several hours of discontinuing quinidine.
- Quinidine raises the digoxin level, generally necessitating a digoxin dose reduction.

Alternative Drugs

- Propranolol—initially administered at a dose of 0.1 to 0.2 mg/kg PO every 8 hours, then titrated upward until an adequate response is obtained. Do not exceed a dose of 0.5 mg/kg PO every 8 hour. Propranolol is poorly tolerated when used chronically and also affects β_2 receptors and is therefore rarely used.

Diet

- Mild to moderate sodium restriction if CHF

Activity

- Restrict activity until tachycardia is controlled.

Appropriate Health Care

- Patients with fast (secondary) atrial fibrillation are treated medically to slow the ventricular rate. Converting the atrial fibrillation to sinus rhythm would be ideal, but such attempts in patients with severe underlying heart disease or left atrial enlargement are generally futile because of a low success rate and high rate of recurrence.
- Consider quinidine or electrical cardioversion to sinus rhythm for a dog with primary atrial fibrillation.
- Patients with primary atrial fibrillation may be converted back to normal sinus rhythm. The success rate depends on chronicity. Patients which have been in atrial fibrillation for fewer than 4 months generally have a lower success rate and a higher rate of recurrence. In these patients, rate control, if necessary, is the recommended treatment.
- Electrical (DC) cardioversion—application of a transthoracic electrical shock at a specific time in the cardiac cycle; requires special equipment, trained personnel, and general anesthesia. A small (10 joules) electrical shock may suffice, but most require higher power (50–150 joules). Biphasic DC cardioversion consistently cardioverts with lower power (<50 joules).

Nursing Care

- As indicated for CHF



COMMENTS

Client Education

- Secondary atrial fibrillation is usually associated with severe underlying heart disease; goal of therapy is to lower heart rate and control clinical signs.
- Sustained conversion to sinus rhythm is unlikely with secondary atrial fibrillation.

Patient Monitoring

- Monitor heart rate and ECG closely.
- Because heart rates in the hospital and those measured on the surface ECG may be inaccurate (due to patient anxiety and other environmental factors), Holter monitoring provides a more accurate means for assessing the need for heart rate control or the efficacy of medical therapy for heart rate control.

Possible Complications

- Worsening of cardiac function with onset of arrhythmia

Expected Course and Prognosis

- Secondary atrial fibrillation—associated with severe heart disease, so a guarded-to-poor prognosis
- Primary atrial fibrillation with normal ultrasound findings—generally a good prognosis

Abbreviations

- AV: atrioventricular
- CHF: congestive heart failure
- DC: direct current
- ECG: electrocardiogram
- IV: intravenously
- PO: by mouth
- SVT: supraventricular tachycardia

Suggested Reading

- Kittleson, MD. Electrocardiography. In: Kittleson, MD, Kienle, RD, eds. *Small Animal Cardiovascular Medicine*, pp.72–94. St. Louis: Mosby, 1998.
- Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Baltimore: Williams & Wilkins, 1992.
- Tilley, LP, Smith, FWK, Oyama, M, and Sleeper, M. *Manual of Canine and Feline Cardiology*, 4th ed.. St. Louis: Saunders/Elsevier, 2008.

Author: Larry P. Tilley

Atrial Standstill



DEFINITION/OVERVIEW

- ECG rhythm characterized by absence of P waves
- Condition can be temporary (e.g., associated with hyperkalemia or drug induced), terminal (e.g., associated with severe hyperkalemia or dying heart), or persistent.

Electrocardiogram Features

Persistent Atrial Standstill (Figure 10.1)

- P waves absent
- Heart rate usually slow (<60 beats per minute)
- Rhythm regular with supraventricular type QRS complexes
- Heart rate does not increase with atropine administration.

Hyperkalemic Atrial Standstill

- Heart rate normal or slow
- Rhythm regular or irregular
- QRS complexes tend to be wide and become wider as the potassium level rises; with severe hyperkalemia (potassium >10 mEq/mL), the QRS complexes are replaced by a smooth biphasic curve.
- Heart rate may increase slightly with atropine.



■ **Figure 10.1** Persistent atrial standstill in English springer spaniel. No P waves are present on any of the leads (also including chest leads and intracardiac electrocardiogram, not shown here). The regular bradycardia is either junctional in origin, with pathologic involvement of the left bundle branch block (wide positive QRS complexes), or ventricular.

From: Tilley, L.P. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Baltimore: Williams & Wilkins, 1992, with permission.



ETIOLOGY/PATHOPHYSIOLOGY

Persistent Atrial Standstill

- Rare condition caused by an atrial muscular dystrophy; skeletal muscle involvement common

Hyperkalemic Atrial Standstill

- Generally occurs with serum potassium levels >8.5 mEq/L; value influenced by serum sodium and calcium levels and acid-base status. Patients who are hyperkalemic with atrial standstill have sinus node function, but impulses do not activate atrial myocytes; thus, the associated rhythm is termed a sinoventricular rhythm. Because the sinus node is functional, an irregular rhythm may be due to sinus arrhythmia.

Systems Affected

- Cardiovascular



SIGNALMENT/HISTORY

Species

- Dog and cat

Breed Predisposition

- Persistent atrial standstill—most common in English springer spaniels; other breeds occasionally affected

Mean Age and Range

- Most animals with persistent atrial standstill are young.
- Animals with hypoadrenocorticism are usually young to middle-aged.
- Any age if associated with uroabdomen or urethral obstruction.

Predominant Sex

- Hypoadrenocorticism more common in females (69 percent)

Historical Findings

- Vary with underlying cause.
- Lethargy common; syncope may occur.
- Patients with persistent atrial standstill may show signs of CHF
- Cats with urinary obstruction may have a history of dysuria or stranguria.



CLINICAL FEATURES

- Vary with underlying cause
- Bradycardia common
- Dogs with persistent atrial standstill may have skeletal muscle wasting of the antebrachium and scapula.



DIFFERENTIAL DIAGNOSIS

- Slow atrial fibrillation
- Sinus bradycardia with small P waves lost in the baseline



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

Persistent Atrial Standstill

- Normal

Hyperkalemic Atrial Standstill

- Hyperkalemia
- Hyponatremia and sodium-to-potassium ratio <27 if atrial standstill secondary to hypoadrenocorticism
- Azotemia and hyperphosphatemia with hypoadrenocorticism, renal failure, and rupture or obstruction of the urinary tract

Other Laboratory Tests

- ACTH stimulation test if hypoadrenocorticism suspected

Imaging

- Echocardiogram and electromyography if persistent atrial standstill suspected; cardiomegaly and depressed contractility may be seen.

Other Diagnostic Tests

- Skeletal muscle biopsy in animals with persistent atrial standstill

Pathologic Findings

Persistent Atrial Standstill

- Greatly enlarged and paper-thin atria; usually biatrial involvement, although one case of only left atrial involvement was reported
- Severe scapular and brachial muscle wasting in some dogs
- Marked fibrosis, fibroelastosis, chronic mononuclear cell inflammation, and steatosis throughout the atria and interatrial septum



THERAPEUTICS

Drug(s) of Choice

Persistent Atrial Standstill

- Treat with diuretics and ACE inhibitor (e.g., enalapril or benazepril) if CHF develops.

Hyperkalemic Atrial Standstill

- Treat the underlying cause (e.g., oliguric renal failure, hypoadrenocorticism).
- Aggressive fluid therapy with 0.9% saline and possibly sodium bicarbonate or insulin with dextrose as will be discussed
- Can administer sodium bicarbonate to patients with severe hyperkalemia to induce translocation of potassium into cells; if blood pH and base deficit cannot be determined, administer 1 to 2 mEq/kg slowly IV. To calculate bicarbonate dose more accurately:
 - Dogs: $0.3 \times \text{body weight (kg)} \times (21 - \text{patient's } \text{HCO}_3^-)$
 - Cats: $0.3 \times \text{body weight (kg)} \times (19 - \text{patient's } \text{HCO}_3^-)$
 - Administer half of dose and reevaluate.
- Can administer dextrose and regular insulin to patients with severe hyperkalemia to induce translocation of potassium into cells (regular insulin, 0.5 U/kg IV with 50% dextrose, 1 g/kg IV); dextrose can also be used without insulin; follow insulin and dextrose administration with 2.5% dextrose as a CRI to prevent hypoglycemia.
- For patients with life-threatening hyperkalemia, administer calcium gluconate 10% (0.5–1 mL/kg slowly IV over 10 minutes) while monitoring the ECG; calcium antagonizes the effect of potassium on the conduction system without lowering the potassium concentration.

Precautions/Interactions

- Avoid potassium-containing fluids or medications that increase potassium concentration in patients who are hyperkalemic.
- Diuretics lower preload and may worsen weakness in dogs with persistent atrial standstill and CHF unless a pacemaker has been implanted.

Activity

- Restrict activity in patients with persistent atrial standstill and signs of CHF or syncope.

Surgical Considerations

Persistent Atrial Standstill

- Implant permanent ventricular pacemaker to regulate rate and rhythm.

Hyperkalemic Atrial Standstill

- Hyperkalemia secondary to urinary tract obstruction or rupture may require surgery.



COMMENTS

Client Education

Persistent Atrial Standstill

- Clinical signs generally improve after pacemaker implantation; signs of CHF may develop, and weakness and lethargy may persist even after heart rate and rhythm are corrected with the pacemaker.

Patient Monitoring

- Monitor ECG during treatment of hyperkalemia and periodically in animals with a permanent ventricular pacemaker.
- Monitor electrolytes in patients with hyperkalemic atrial standstill.
- Monitor patients with persistent atrial standstill for signs of CHF.

Possible Complications

- CHF in patients with persistent atrial standstill

Expected Course and Prognosis

Persistent Atrial Standstill

- Clinical signs generally improve after pacemaker implantation. Signs of CHF may develop, and weakness and lethargy persist even after heart rate and rhythm are corrected with the pacemaker. There may be persistence of signs related to muscular dystrophy.

Hyperkalemic Atrial Standstill

- Long-term prognosis is excellent if underlying cause can be corrected and hyperkalemia reversed.

Synonyms

- Silent atria

Abbreviations

- ACE: angiotensin-converting enzyme
- ACTH: adrenocorticotrophic hormone
- CHF: congestive heart failure
- CRI: constant rate infusion
- ECG: electrocardiogram
- HCO_3^- : bicarbonate
- IV: intravenously
- pH: measure of acidity or base

Suggested Readings

- Gavaghan, BJ, Kittleson, MD, and McAloose, D. Persistent atrial standstill in a cat. *Aust Vet J* 1999;77(9):574–579.
- MacAulay, K. Permanent transvenous pacemaker implantation in an Ibizan hound cross with persistent atrial standstill. *Can Vet J* 2002;43(10):789–791.
- Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Philadelphia: Lea & Febiger, 1992.
- Wess, G, Thomas, WP, Berger, DM, and Kittleson, MD. Applications, complications, and outcomes of transvenous pacemaker implantation in 105 dogs (1997–2002). *J Vet Intern Med* 2006; 20(4):877–884

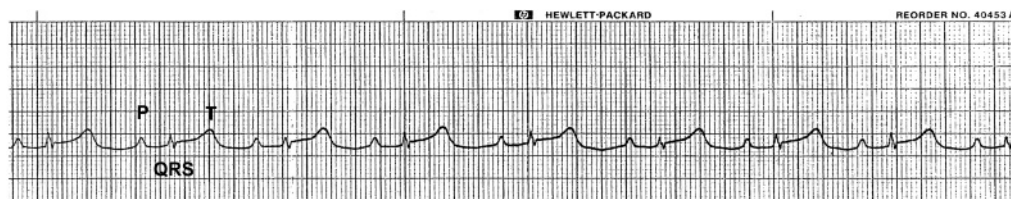
Author: Francis W. K. Smith, Jr.

Atrioventricular (AV) Block

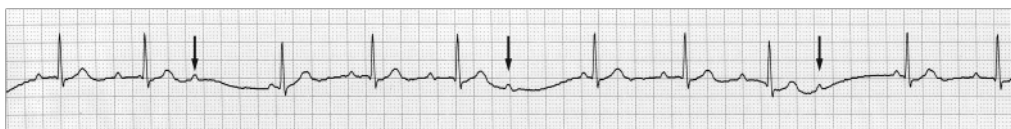


DEFINITION/OVERVIEW

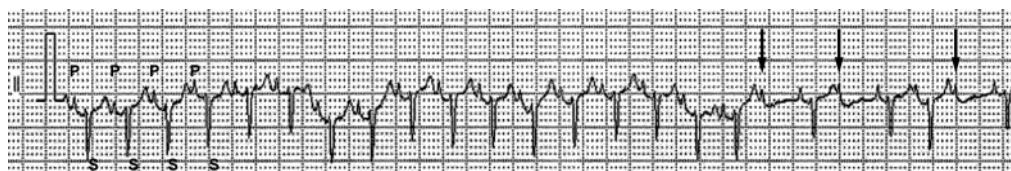
- AV block refers to a delay or block of impulse conduction from the atria to the ventricles at a time when the conduction system is not refractory.
- Conduction delay or block may arise at any site between the sinoatrial node and the ventricular myocardium (i.e., intra-atrial, intranodal, or subnodal block).
- While certain ECG patterns of AV block more typically reflect impaired conduction in one particular segment of the cardiac conduction system, overlap occurs, and it is often impossible to determine with certainty which part of the conduction system is responsible for the block based on the surface ECG.
- AV block is classified into three categories based on electrocardiographic characteristics:
 1. First-degree AV block refers to delayed AV conduction.
 - The ECG shows a 1:1 relationship of P waves and QRS complexes with a prolonged PR interval (>0.13 seconds in dogs and >0.09 seconds in cats).
 - QRS and T waves usually appear normal (Figure 11.1).
 2. Second-degree AV block occurs when there is failure of some, but not all, P waves to be conducted to the ventricles; three patterns of second-degree AV block are recognized.
 - Mobitz Type I (Wenckebach) second-degree AV block is characterized by gradual prolongation of PR intervals until a P wave fails to conduct (Figure 11.2).
 - Mobitz Type II second-degree AV block is characterized by abrupt failure of one or more consecutive P waves to be conducted without progressive lengthening of the PR interval prior to the blocked P wave (Figure 11.3).
 - High-grade second-degree AV block is characterized by a fixed ratio of P waves to QRS complexes, for example, 2:1, 3:1, 4:1 (Figure 11.4). (This type of second-degree AV block cannot be classified as Type I or Type II.)
 - QRS and T waves appear normal unless there is also an intraventricular conduction abnormality.
 3. Third-degree (complete) AV block is the result of complete absence of AV conduction.
 - Characterized on ECG (in patients with sinus rhythm or other organized atrial rhythm) as a complete lack of association of P waves and QRS complexes with the ventricular rate slower than the atrial rate



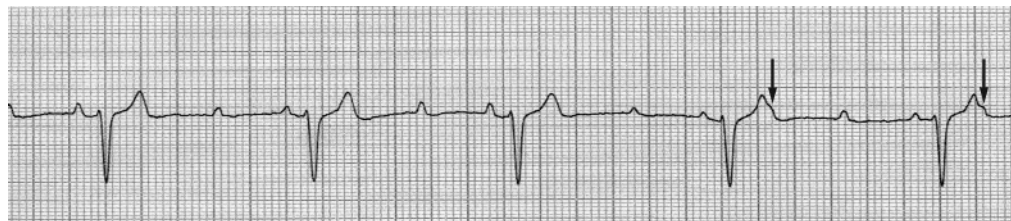
■ **Figure 11.1** A lead II electrocardiogram rhythm strip recorded from an eight-year-old cat is shown. There is sinus bradycardia (120 beats per minute) and first-degree atrioventricular block. A P wave precedes each QRS complex with a constant, but prolonged, PR interval of 0.14 second (paper speed = 50 mm/s).



■ **Figure 11.2** Shown is a lead II electrocardiogram rhythm strip recorded from a dog with Mobitz Type I second-degree atrioventricular block. Nonconducted P waves are indicated by arrows. The PR interval becomes progressively longer with the longest interval preceding a nonconducted P wave (paper speed = 50 mm/s).

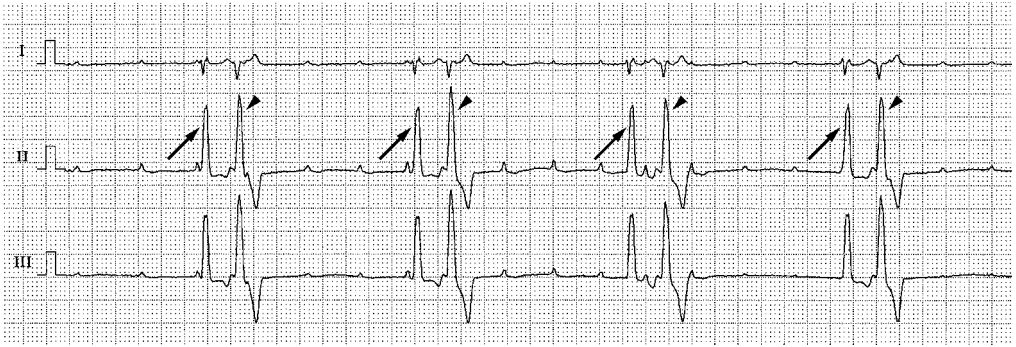


■ **Figure 11.3** A lead II electrocardiogram rhythm strip recorded from a cat with Mobitz Type II second-degree atrioventricular block is shown. There are intermittent nonconducted P waves (arrows); however, the PR interval of conducted beats is constant (0.09 second). The QRS complexes are abnormal (rS pattern) because of concomitant left anterior fascicular block (paper speed = 25 mm/s).

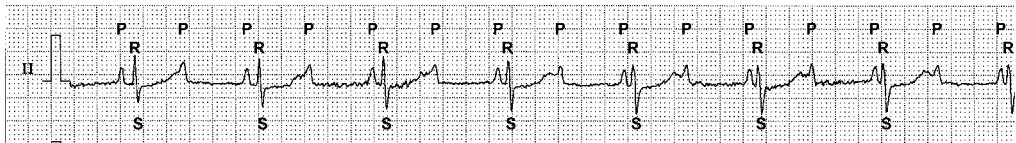


■ **Figure 11.4** Shown is a lead II rhythm strip recorded from a dog with bradycardia (ventricular rate = 62 beats per minute) as a result of high grade second-degree atrioventricular block occurring in a 3:1 conduction pattern. The initial P wave of each cycle is hidden by the preceding T wave; however, these P waves can occasionally be appreciated deforming the T wave (arrows). The QRS complexes are abnormal (wide and negative) because the dog also has right bundle branch block (paper speed = 25 mm/s).

- Because ventricular depolarization arises from escape activity of a subsidiary intraventricular pacemaker, QRS complexes are typically wide and bizarre (Figure 11.5).
- In many cats and some dogs, the escape focus is near the origin of the His bundle (in the region defined as the AV junction), and in these animals, the QRS complexes are narrow (Figure 11.6).



■ **Figure 11.5** Shown is a simultaneous lead I, II, and III electrocardiogram recording from a dog with complete (third-degree) atrioventricular block. The atrial rate (136 beats per minute) exceeds the ventricular rate, and there is no relationship between P waves and QRS complexes. There is a ventricular escape focus depolarizing the ventricular myocardium at a regular rate of 32 beats per minute. These QRS complexes are abnormally wide (0.09s) with a left bundle branch morphology (arrows). Each of the ventricular escape complexes is coupled to a premature ventricular contraction (arrowheads; paper speed = 25 mm/s).



■ **Figure 11.6** This lead II electrocardiogram was recorded from a cat with complete (third-degree) atrioventricular block. The atrial rate (214 beats per minute) exceeds the ventricular rate (109 beats per minute), and there is no relationship between P waves and QRS complexes. The morphology of the QRS complexes is normal indicating a junctional escape focus (paper speed = 50 mm/s).



ETIOLOGY/PATHOPHYSIOLOGY

- A variety of disorders or disease processes may cause impaired AV conduction, and the severity of impairment may range from first-degree to complete AV block in each of these circumstances.
- AV block may be transient or permanent.
- AV block may progress from first-degree to more severe block.
- AV block may result from intrinsic disease of the cardiac conduction system or from extrinsic factors adversely affecting impulse conduction.
- Any condition that increases vagal tone may produce varying degrees of AV block:
 - Vagal stimulation is a common cause of AV conduction block in the critical care setting.
 - Second-degree AV block occurs in 64 percent of healthy adult dogs and 100 percent of healthy pups between 8 and 11 weeks of age.
 - Vagal tone is increased during sleep; therefore, AV block may disappear during waking hours and with resumption of normal activity.
 - Valsalva maneuvers may also result in transient AV block.

- Enhanced vagal tone in dogs and cats may be associated with conditions such as upper airway disease, cervical and thoracic masses, gastrointestinal disorders, head or neck trauma, increased CSF pressure, and glaucoma.
- Electrolyte imbalances may predispose to or cause AV block (hyperkalemia directly impairs AV conduction, whereas hypokalemia enhances the effect of vagal stimulation).
- Other extrinsic causes of AV conduction block include drugs or toxins such as cardiac glycosides, β -adrenergic antagonists, calcium channel blocking agents, propafenone, amiodarone, α_2 -adrenergic agonists, parasympathomimetic agents, or severe procainamide or quinidine toxicity.
- Transient potentiation of AV block may be seen following administration of atropine, and bradycardic potentiation is longer in duration with subcutaneous administration.
- AV block as a result of disorders of the cardiac conduction system include:
 - Degeneration of the conduction system (AVN, bundle of His, or bundle branches) with or without degenerative mitral valve disease
 - Inflammation affecting the AVN, atrial approaches to the AVN, or Purkinje system including bacterial endocarditis of the aortic valve and myocarditis (*Borrelia burgdorferi*, *Trypanosoma cruzi*, *Rickettsia rickettsii*, tetanus, lymphocytic-plasmacytic myocarditis)
 - Infiltrative diseases (tumors, amyloid)
 - Cardiomyopathy
 - Congenital AV block associated with structural defects (e.g., atrioventricular septal defects) or primary congenital AV block (pugs; Airedale terriers)
 - Severe systemic hypertension
 - Blunt chest trauma
 - Ischemia or infarction (rare)

Systems Affected

- Cardiovascular system (bradycardia, hypoperfusion, and hypotension if AV block is high grade second or third degree)
- Neuromuscular system (may be affected secondarily from significant bradycardia and hypoperfusion)
- Renal (azotemia may result from profound or chronic hypoperfusion)



SIGNALMENT/HISTORY

- Both dogs and cats
- Breed predilections: American cocker spaniels (degenerative AV block), dachshunds (degenerative AV block), Doberman pinschers, brachycephalic dogs (vagal mediated AV block), Persian cats (vagal mediated AV block)
- Young, otherwise healthy dogs as a manifestation of high vagal tone

- Young animals with congenital heart disease
- Older dogs and cats with degenerative conduction system disease
- Cats of any age with hypertrophic or restrictive cardiomyopathy

Risk Factors/Causes

- Any condition or intervention that increases vagal tone

Historical Findings

- Many animals are asymptomatic
- Syncope or collapse
- Exercise intolerance
- Occasionally seizures
- May have a variety of clinical signs resulting from underlying cause



CLINICAL FEATURES

Physical Examination Findings

- Normal with first-degree AV block (unless there are also abnormalities resulting from more generalized myocardial disease or noncardiac disease).
- Dogs with profound bradycardia may appear weak.
- Intermittent pauses in the cardiac rhythm with Mobitz Type I or Type II second-degree AV block
- Bradycardia if high-grade second-degree or third-degree block
- Jugular veins may show intermittent cannon A waves with third-degree block.
- First heart sound (S1) may become progressively softer, followed by a pause with Mobitz Type I second-degree AV block.
- An audible S4 may be heard unaccompanied by S1 and S2 when block occurs (second- and third-degree AV block).
- A systolic ejection murmur resulting from relative aortic stenosis may be heard in patients with bradycardia.
- Secondary neurologic signs (e.g., seizures, extensor rigidity) may be noted in animals with severe bradycardia.
- Premature beats or paroxysms of tachycardia secondary to myocardial hypoperfusion may be audible in animals with severe bradycardia.
- Other abnormalities reflecting the underlying etiology may be observed.



DIFFERENTIAL DIAGNOSIS

- Sinus node dysfunction (sick sinus syndrome)
- Atrial standstill

- Accelerated idioventricular rhythm
- P waves superimposed upon preceding T waves because of first-degree AV block should be differentiated from bifid T waves.
- Nonconducted P waves from supraventricular premature impulses or supraventricular tachycardia should be distinguished from second-degree AV block.



DIAGNOSTICS

- Standard electrocardiography
- Continuous ECG monitoring or recording (e.g., Holter monitoring, event recording, telemetry) may be required if conduction impairment is intermittent.
- May be necessary to identify specific noncardiac causes of enhanced vagal tone.
- Atropine response test may be used to determine whether AV block is due to vagal tone (administer atropine 0.04 mg/kg IM and repeat ECG in 20–30 minutes).
- Hyperkalemia and hypokalemia may predispose to AV conduction disturbances.
- Abnormal leukogram may be noted in animals with bacterial endocarditis or myocarditis.
- Serum digoxin concentration may be high.
- High T₄ in cats if associated with thyrotoxic myocardial disease
- Abnormally high arterial blood pressure if associated with severe hypertension or hypertensive cardiac disease.
- Positive *Borrelia*, *Rickettsia*, or *Trypanosoma cruzi* titers if associated with one of these infectious agents
- Blood cultures may be positive in patients with bacterial endocarditis.
- Electrophysiologic studies are generally unnecessary but can be done to confirm the specific type of AV block if surface ECG findings are equivocal and to identify the specific intracardiac location of the conduction block.
- Doppler/echocardiographic examination may reveal structural heart disease (e.g., endocarditis, neoplasia, cardiomyopathy).

Pathologic Findings

- No gross or histopathologic abnormalities if AV block is due to extrinsic causes.
- With cardiac conduction system disorders findings may vary depending on the underlying cause.
- Older animals with degenerative change of the conduction system may have focal mineralization of the interventricular septal crest visible grossly; chondroid metaplasia of the central fibrous body and increased fibrous connective tissue in the AV bundle are noted histopathologically.



THERAPEUTICS

- The overall objectives of treatment are to eliminate or reverse the underlying cause and to provide a heart rate support when necessary.

Drug(s) of Choice

- Medications are chosen if appropriate to manage an underlying cardiac or noncardiac condition.
- Temporary or permanent cardiac pacing may be the only consistently effective treatment in symptomatic patients or patients with progressive renal dysfunction due to bradyarrhythmia.
- Atropine (0.02–0.04 mg/kg IV, IM) or glycopyrrolate (0.005–0.01 mg/kg IV, IM) may be used short term if positive atropine response.
- Chronic anticholinergic therapy (propantheline 0.5–2.0 mg/kg PO every 8–12 hours or hyoscyamine 0.003–0.006 mg/kg every 8 hours) for symptomatic patients if improved AV conduction documented with atropine response test.
- Isoproterenol (0.04–0.09 µg/kg per minutes IV to effect) or dopamine (3–5 µg/kg per minute IV to effect) may be administered in acute, life-threatening situations to enhance AV conduction or accelerate an escape focus.

Precautions/Interactions

- Hypokalemia—increases sensitivity to vagal tone; may potentiate AV conduction delay
- Drugs with vagomimetic action (e.g., digoxin, bethanechol, physostigmine, and pilocarpine) may cause or potentiate AV block.
- Avoid drugs likely to impair impulse conduction further or depress a ventricular escape focus (e.g., procainamide, quinidine, lidocaine, calcium channel blocking agents, β -adrenergic antagonists, α_2 -adrenergic agonists, amiodarone, and propafenone).
- Temporary cardiac pacing may induce pacemaker dependency by suppressing an escape focus.
- Avoid the use of isoproterenol or dopamine in patients with digoxin toxicity or ischemic heart disease.

Diet

- Modifications or restrictions only to manage an underlying condition

Activity

- Cage rest advised for symptomatic patients

Surgical Considerations

- Many patients are a high anesthetic risk, and perioperative temporary pacing is advised if anesthesia is needed.
- Permanent artificial cardiac pacemaker may be required for long-term management of symptomatic patients or those with progressive renal dysfunction due to bradyarrhythmia.

- For patients needing a permanent pacemaker, an epicardial system should be considered in those with existing or potential hypercoagulable state, those requiring immunosuppression for a comorbid state, those with sepsis, and feline patients.



COMMENTS

Client Education

- Explain that treatment is directed toward underlying cause.
- Explain that positive chronotropic agents may not be effective long term.
- Explain that cardiac pacing will not prevent progression of underlying heart disease if present.

Patient Monitoring

- Asymptomatic patients without a pacemaker must be monitored for development of clinical signs, secondary congestive heart failure, and progressive renal dysfunction.
- Monitor ECG of patients with first-degree AV block or low-grade second-degree AV block for development of higher grade conduction block.

Expected Course and Prognosis

- Depends on underlying cause
- Prognosis for first-degree and Mobitz Type I second-degree AV block is usually excellent if no significant underlying disease is present.
- AV block may be reversible if due to medications, transient ischemia, blunt trauma, hypertension, electrolyte disorders, or acute myocarditis of any cause.
- Conditions that cause necrosis, disruption, or replacement of the cardiac conduction system cells typically result in progressive and permanent AV block (e.g., infarction, surgical disruption, radiofrequency ablation, bacterial endocarditis, neoplasia, amyloidosis, progressive muscular dystrophy, or cardiomyopathy).
- With high-grade second-degree or complete AV block sudden death may occur.

Synonyms

- Mobitz Type I second-degree AV block: Wenckebach block
- Third-degree AV block: complete AV block
- PR interval: PQ interval

Abbreviations

- AV: atrioventricular
- AVN: atrioventricular node
- CSF: cerebrospinal fluid

- ECG: electrocardiogram
- IM: intramuscularly
- IV: intravenously
- PO: by mouth

Suggested Reading

- Branch, CE, Robertson, BT, and Williams, JC. Frequency of second-degree atrioventricular heart block in dogs. *Am J Vet Research* 1975;36:925–929.
- Kaneshige, T, Machida, N, Yamamoto, S, Nakao, S, and Yamane, Y. A histological study of the cardiac conduction system in canine cases of mitral valve endocardiosis with complete atrioventricular block. *J Comp Pathol* 2007;136:120–126.
- Kellum, HB, and Stepien, RL. Third-degree atrioventricular block in 21 cats. *J Vet Intern Med* 2006;20:97–103.
- Kocovic, DZ, and Friedman, PL. Atrioventricular nodal block. In: Podri, PJ, and Kowey, PR, eds. *Cardiac Arrhythmia Mechanisms, Diagnosis, and Management*, pp. 1039–1050. Baltimore: Williams & Wilkins, 1995.
- Raffe, MR, and O'Toole, E. Arrhythmias in critical care. In: Wingfield, WE, and Raffe, MR, eds. *The Veterinary ICU Book*, pp. 488–523. Jackson Hole, WY: Teton NewMedia, 2002.

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Blood Transfusion Reaction



DEFINITION/OVERVIEW

- An adverse effect resulting from a blood or blood component transfusion



ETIOLOGY/PATHOPHYSIOLOGY

- Transfusion reactions are either acute (within 48 hours of administration) or delayed, and can result from immune-mediated or nonimmune-mediated causes. Transfusion reactions can range from mild and subclinical to severe and life-threatening.

Acute Immune-Mediated Reactions

- Acute hemolysis (type II hypersensitivity) occurs when the recipient possesses antibodies against the RBCs in the transfusion. IgM and IgG are able to fix complement and cause intravascular hemolysis. Extravascular hemolysis occurs with removal of antibody-coated RBCs by the lymphoreticular system. Dogs require previous exposure to develop antibodies; cats possess naturally occurring alloantibodies and may develop acute hemolysis with their first transfusion.
- An allergic reaction (type I hypersensitivity) results from antigen binding with the recipient's IgE or IgG. Antigen–antibody interaction causes degranulation of mast cells, release of numerous vasoactive compounds, systemic inflammation, and vasodilation. Donor leukocytes in the transfusion may also degranulate during storage.
- A febrile nonhemolytic transfusion reaction is caused by interaction of antigens on donor leukocytes or platelets with recipient antibodies or by release of pyrogenic cytokines during storage.

Delayed Immune-Mediated Reactions

- Delayed hemolysis occurs when the recipient develops antibodies from exposure to foreign RBC antigens in the transfusion. These antibodies adhere to transfused RBCs and cause extravascular hemolysis.
- Posttransfusion purpura is an immune-mediated thrombocytopenia that develops secondary to foreign platelet antigens in a transfusion.

Acute Nonimmune-Mediated Reactions

- Hemolysis of donor RBCs before transfusion is caused by improper storage (i.e., outdated product, inappropriate temperature) or administration (excessive pressure, small needle or catheter, concurrent administration of fluids other than 0.9% saline, rapid infusion, and infusion through some fluid pumps).
- Bacterial contamination from improper collection or storage, donor bacteremia, skin contamination, or contamination during administration may lead to septic shock, DIC, and MODS.
- Volume overload can occur with transfusion at an excessive rate or volume because blood products are colloidal suspensions that primarily contribute to intravascular fluid volume. Hypervolemia increases pulmonary capillary pressure and can lead to pulmonary edema.
- Citrate toxicosis may result from administration of large volumes of whole blood. Citrate anticoagulant causes hypocalcemia by chelation and depletion of the recipient's ionized calcium fraction.
- Hyperammonemia from administration of outdated blood products will cause signs of CNS toxicity and can also cause vomiting.
- Hypothermia can be caused or exacerbated by administration of blood products that are not properly warmed, especially in large-volume transfusions.

Delayed Nonimmune-Mediated Reactions

- Transmission of infectious diseases, including *Babesia spp.*, *Ehrlichia canis*, FeLV, FIV, and hemotropic mycoplasma
- Hemosiderosis may occur with repeated or large transfusions causing hepatic damage secondary to iron storage.

Systems Affected

- Hematologic/Lymphatic/Immune—hemolysis
- Cardiovascular—tachycardia, hypotension, volume overload, dysrhythmias
- Respiratory—tachypnea, bronchoconstriction, pulmonary edema
- Gastrointestinal—vomiting, diarrhea
- Skin—erythema, urticaria, pruritus, purpura, angioneurotic edema
- Neuromuscular—tremors or tetany with citrate toxicosis
- Neurologic—encephalopathy
- Hepatic—hemosiderosis
- Coagulation—hypothermia-induced coagulopathy, posttransfusion purpura, DIC

Incidence/Prevalence

- Reported rates of canine transfusion reactions range from 3.3 to 40 percent.
- Common—febrile nonhemolytic reactions
- Rare—posttransfusion purpura, citrate toxicosis, hemosiderosis

Geographic Distribution

- Cats with type B blood are found more commonly in Europe, Japan, Australia, and the Pacific Northwest portion of the United States.



SIGNALMENT/HISTORY

- Purebred cats, particularly British shorthair and Devon rex, have a higher frequency of type B blood, which carries a greater risk of incompatibility because the majority of cats in the United States are type A. Type B cats tend to react strongly to type A blood and can have a fatal reaction within hours of transfusion.

Signs

- Acute hemolysis—hemoglobinemia/hemoglobinuria with intravascular hemolysis, generally milder signs with extravascular hemolysis, vomiting, diarrhea, pyrexia, tachycardia, tachypnea, hypotension, dysrhythmias, seizures
- Allergic reactions—pyrexia, erythema, urticaria, pruritus, angioneurotic edema, vomiting, diarrhea, and possible anaphylaxis with hypotension, tachycardia, and bronchoconstriction
- Febrile nonhemolytic reaction—temperature increase of $>1^{\circ}\text{C}$, pyrexia may persist for up to 20 hours
- Delayed hemolysis—typically mild decrease in PCV without hemoglobinuria
- Posttransfusion purpura—petechiae, ecchymoses, spontaneous hemorrhage, usually 7 to 14 days post-transfusion
- Nonimmune-mediated hemolysis—typically benign but reduced efficacy of the transfusion
- Bacterial contamination—pyrexia, vomiting, hemolysis, septic shock
- Volume overload—tachypnea, moist cough, orthopnea, cyanosis
- Citrate toxicosis—tremors, tetany, nausea, hypotension, dysrhythmias
- Hyperammonemia—ataxia, dementia, head pressing, circling, seizures, vomiting
- Hypothermia—decrease in body temperature, dysrhythmias

Risk Factors/Causes

- Transfusion carries an inherent risk of reaction.
- Acute hemolysis—previous transfusion or pregnancy
- Allergic reactions—worse with plasma or platelet transfusions
- Febrile nonhemolytic reaction—risk increases with storage time of the product
- Bacterial contamination—platelet products, which may be stored at room temperature
- Volume overload—cats, neonates, underlying cardiopulmonary disease, oliguric/anuric renal failure, whole blood transfusions and infusion of hemoglobin-based oxygen carriers (e.g. Oxyglobin) tend to be of a larger volume

- Citrate toxicosis—hepatic dysfunction, whole blood transfusion, rapid or large-volume transfusion
- Hyperammonemia—hepatic dysfunction, ammonia levels in blood products increase with storage time
- Hypothermia—large volume transfusion, transfusion through a central line



DIFFERENTIAL DIAGNOSIS

- Although acute transfusion reactions may appear similar clinically, correct diagnosis is necessary for appropriate treatment. If a reaction is suspected, confirm product–recipient compatibility, expiration date, and evaluate the appearance of the product for signs of contamination. The presence of hemoglobinemia or hemoglobinuria strongly suggests hemolysis but may be absent with extravascular hemolysis.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- PCV—rapid decline with acute hemolysis, mild-to-marked decrease with delayed hemolysis, pink- to red-tinged plasma portion
- Thrombocytopenia—mild to marked with posttransfusion purpura
- Hemoglobinemia/hemoglobinuria—acute hemolysis
- Hyperbilirubinemia—acute or delayed hemolysis

Other Laboratory Tests

- Coombs' test—positive in delayed hemolytic reactions but may be positive from primary disease
- Gram stain and culture—if bacterial contamination is suspected
- Ionized calcium—low with citrate toxicosis
- Ammonia level—high with hyperammonemia but difficult to test

Imaging

- Thoracic radiographs—confirm volume overload, patchy interstitial to alveolar lung pattern, can develop anywhere, but more common in the perihilar region

Diagnostic Procedures

- Cross-match—confirm compatibility
- Blood pressure—hypotension with acute hemolysis or anaphylaxis; hypertension with volume overload
- Pulse oximetry—hypoxemia with acute hemolysis, anaphylaxis, and volume overload

- Central venous pressure—sharp increase with volume overload
- ECG—bradycardia, Q-T interval prolongation, and VPCs with citrate toxicosis



THERAPEUTICS

- The transfusion should immediately be discontinued whenever a reaction is suspected and the patient fully evaluated to determine appropriate treatment.
- Acute hemolysis—discontinue transfusion, support systemic blood pressure with intravenous fluids \pm vasopressors; oxygen supplementation if hypoxemic; corticosteroids not generally indicated
- Allergic reactions—discontinue or decrease rate of transfusion, antihistamine \pm corticosteroid; epinephrine, oxygen supplementation, intravenous fluid therapy, and vasopressors may be needed with anaphylaxis
- Febrile nonhemolytic reaction—decrease rate of transfusion, medications usually not necessary but consider antihistamines \pm NSAIDs
- Delayed hemolysis—therapy usually not indicated, additional transfusions may be required with severe anemia
- Bacterial contamination—discontinue transfusion, broad-spectrum intravenous antibiotic therapy
- Volume overload—discontinue or decrease rate of transfusion, oxygen supplementation, diuretic therapy
- Citrate toxicosis—discontinue or decrease rate of transfusion, slow administration of intravenous calcium

Drug(s) of Choice

- Allergic reaction—diphenhydramine (2 mg/kg IM) \pm a short-acting corticosteroid if signs progress or do not improve, epinephrine (0.01 to 0.02 mg/kg SQ, IM, or IV) for anaphylaxis
- Posttransfusion purpura—immunosuppressive dose of corticosteroids in severe cases
- Volume overload—furosemide (2–4 mg/kg IV, repeat every 30 minutes until clinical signs of orthopnea resolve)
- Citrate toxicosis—calcium gluconate (94–140 mg/kg slowly IV)

Contraindications

- Avoid using corticosteroids or NSAIDs in patients with gastrointestinal hemorrhage.

Precautions/Interactions

- Administration of calcium in the same line with blood products may cause clot or precipitate formation.



COMMENTS

Patient Monitoring

- Quick recognition allows earlier and more successful treatment of transfusion reactions. Baseline temperature, pulse, respiratory rate, and CRT at baseline and every 15 minutes for the first hour then hourly until transfusion is complete
- Pre- and posttransfusion PCV

Prevention/Avoidance

- Critically assess the patient's needs and avoid transfusion if not clinically warranted.
- When taking history, ask about previous transfusion and prominently note transfusion history in patient records.
- Confirm donor–recipient compatibility by typing or cross-matching.
- Choose the appropriate blood product containing only needed components with minimal antigen and volume.
- Do not administer products that are outdated or abnormal in appearance.
- Administer blood products with proper equipment.
- Leukoreduction (removal of leukocytes from a blood product) may reduce the likelihood of a febrile nonhemolytic reaction.
- Bacterial contamination can be prevented by aseptic collection technique, sterile collection equipment, and proper storage.
- Sufficiently warm blood products with an approved warming device
- Thorough screening of donors for potential infectious diseases
- Prophylactic administration of antihistamines or glucocorticoids is controversial but not supported by scientific evidence and is not recommended at this time.

Abbreviations

- CNS: central nervous system
- CRT: capillary refill time
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- FeLV: feline leukemia virus
- FIV: feline immunodeficiency virus
- IgE: immunoglobulin E
- IgG: immunoglobulin G
- IgM: immunoglobulin M
- IM: intramuscularly
- IV: intravenously
- MODS: multiorgan dysfunction syndrome
- NSAID: nonsteroidal anti-inflammatory drug

- PCV: packed cell volume
- RBC: red blood cell
- SQ: subcutaneously
- VPC: ventricular premature contraction

Suggested Reading

Bracker, KE, and Drellich, S. Transfusion reactions. *Comp Cont Educ Pract Vet* 2005;27:500–512.

Lanevski, A, and Wardrop, J. Principles of transfusion medicine in small animals. *Can Vet J* 2001;42:447–454.

Prittie, JE. Triggers for use, optimal dosing, and problems associated with red cell transfusions. *Vet Clin Small Anim* 2003;33:1261–1275.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Jorg Bucheler

Brachial Plexus Injury



DEFINITION/OVERVIEW

- TBPI is a catch-all term that refers to traumatically induced neuropathy of the C6–T2 ventral spinal nerve rami.



ETIOLOGY/PATHOPHYSIOLOGY

- The brachial plexus originates from the ventral rami of the C6–T2 spinal nerves.
- Its projections comprise the suprascapular (C6–C7), subscapular (C6–C7), musculocutaneous (C6–C8), axillary (C6–C8), radial (C6–T2), median (C8–T2), ulnar (C8–T2), and lateral thoracic (C8–T1) nerves.
- Thoracic limb traction or abduction can result in injury to the brachial plexus or associated structures.
- Injury can lead to neuropraxia (focal demyelination without axonal disruption), axonotomesis (axonal injury with sparing of the endoneurium), or neurotomy (complete severance of axons and ensheathing tissues).
- When neurotomy occurs, it is often at the level of the nerve rootlets, and results in brachial plexus avulsion.



SIGNALMENT/HISTORY

- Young, male, large breed dogs with unsupervised outdoor access are likely predisposed.

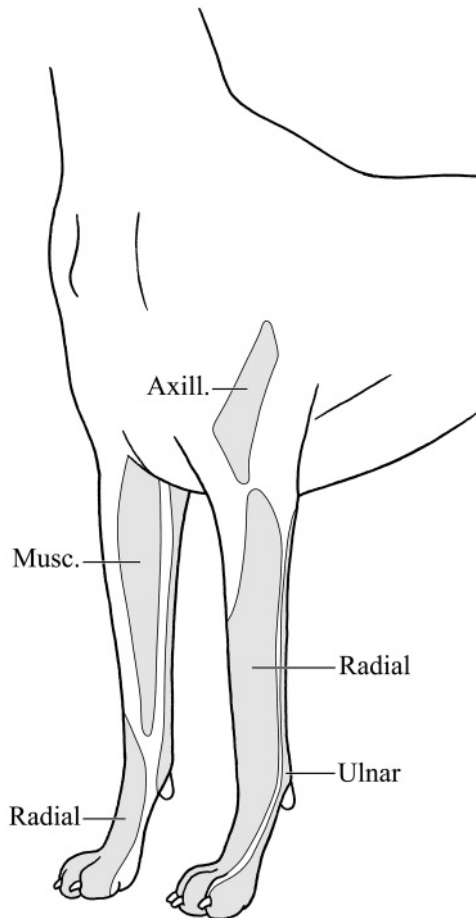


CLINICAL FEATURES

- TBPI can be classified as complete, cranial (C6–C7) or caudal (C8–T2).
- Ventral rootlets and associated motor fibers are most susceptible to TBPI, although sensory projections can be affected in severe injuries.

Cranial Traumatic Brachial Plexus Injury

- Lesions associated with the cranial brachial plexus will result in difficulty advancing the limb at the shoulder (suprascapular nerve), shoulder instability (suprascapular, subscapular nerves), and weak elbow flexion (musculocutaneous nerve).
- Animals with cranial TBPI usually have the ability to bear weight and extend the elbow as the majority of the radial distribution will be spared.
- Postural reactions may be weak, although sparing of the knuckling response is common.
- The extensor carpi radialis and triceps reflexes are likely to be preserved, whereas the biceps and flexor withdrawal reflexes may be weak.
- In severe cranial TBPI cutaneous hypalgesia or analgesia may be present. Avulsion of the C6–C8 nerve roots leads to analgesia in the autonomous zone of the axillary nerve (lateral brachium), musculocutaneous nerve (craniomedial antebrachium), and portions of the radial nerve (cranial antebrachium, dorsum of paw) (Figure 13.1).



■ **Figure 13.1** The major autonomous zones of the thoracic limb of the dog.

Caudal Traumatic Brachial Plexus Injury

- Caudal TBPI will lead to an inability to bear weight on the thoracic limb and loss of carpal extension.
- Proximally located lesions involving the ventral rootlets, ventral roots, or spinal nerves associated with T1–T2 may lead to ipsilateral Horner's syndrome.
- Lesions involving C8–T1 (lateral thoracic nerve) may lead to ipsilateral loss of the cutaneous trunci reflex.
- Postural reactions, such as hopping or knuckling, will be weak or absent depending on the severity of caudal TBPI.
- Reflexes, including the flexor withdrawal, extensor carpi radialis, and triceps, will be weak or absent.
- Hypalgesia or analgesia may be present in the autonomous zones of the ulnar (caudal antebrachium) and radial (cranial antebrachium, dorsum of paw) with C8–T2 TBPI.

Complete Traumatic Brachial Plexus Injury

- Complete TBPI has the features of both cranial and caudal TBPI, with analgesia to the entire limb distal to the elbow occurring with severe lesions.
- In some cases of proximally located complete TBPI, postural reaction deficits, upper motor neuron paresis and ataxia may be present in the ipsilateral pelvic limb due to hematoma compression of the spinal cord.



DIFFERENTIAL DIAGNOSIS

- Other differential diagnoses for acute onset monoparesis or monoplegia of a thoracic limb in dogs include:
 - FCE
 - Lateralized disk herniation
 - Brachial plexus neuritis (can be bilateral)
 - Infectious neuritis
 - Neoplasia
 - Vascular neuromyopathy (brachial artery occlusion)



DIAGNOSTICS

- Frequently TBPI is diagnosed based on clinical signs and a history of trauma.
- All animals should receive a careful physical examination, with special attention paid to intrathoracic, intra-abdominal, orthopedic, and neurologic structures that may be concurrently injured.

- Animals with a history of significant trauma should have a complete blood count, serum biochemistry profile, urinalysis, and chest radiograph series.
- Those patients with discrete abnormalities in any particular system should have those investigated appropriately.
- Advanced imaging, such as CT or MRI, of the brachial plexus, spinal nerves, nerve rootlets, and spinal cord can help to exclude other etiologies.
- Electrophysiology, which can include EMG, motor and sensory nerve conduction velocity, and cord dorsum potentials, can be performed.
- The value of electrophysiology is that it can identify specific nerve and muscle groups involved as well as separate neuropraxic injuries from those that involve the axon and may have a poorer prognosis.
- Electrophysiology is usually performed at least 8 days after injury as in dogs with axonal damage, because this is the time that it will take to develop abnormal spontaneous activity on EMG.
- Electrophysiology does not discern the etiology responsible for neuropathy.



THERAPEUTICS

- Animals with injuries to other body systems should have those addressed.
- Treatment of TBPI has traditionally consisted of physical rehabilitation and analgesia.
- Passive range of motion exercises, active weight bearing, electrical muscle stimulation, and underwater treadmill may all be of benefit.
- In the acute phase of TBPI opioid analgesia and NSAIDs may be required.
- Some animals may develop neuropathic pain in the chronic phases of recovery, manifested by licking or chewing the limb. These animals may require agents such as gabapentin or tricyclic antidepressants.
- Steroids are of unknown value in the acute or chronic phases of TBPI.
- Animals with absent nociception often do not recover function of the limb and may need limb amputation.
- Recently, techniques for nerve transposition and re-implantation have been developed that may improve functional recovery in animals with brachial plexus avulsion. Unfortunately, few veterinary surgeons or neurologists in the United States are able to perform these procedures.

Drug(s) of Choice

Opioids

- Buprenorphine: 0.005 to 0.02 mg/kg IV, IM, or SQ two to three times a day
- Fentanyl: 2 to 5 µg/kg IV bolus; continue as CRI at 3 to 5 µg/kg per hour
- Tramadol: 3 to 5 mg/kg PO three to four times a day
- CR Morphine: 1 to 5 mg/kg PO twice a day

Nonsteroidal Anti-Inflammatory Drugs

- Carprofen: 2.2 mg/kg PO twice a day
- Deracoxib: follow manufacturer's instructions
- Meloxicam: 0.2 mg/kg PO every 24 hours

Drugs for Neuropathic Pain

- Amantadine: 3 to 5 mg/kg PO every 24 hours
- Amitriptyline: 1 to 2 mg/kg PO twice a day
- Gabapentin: 3 to 5 mg/kg PO twice a day as starting dose, with a maximum up to 50 mg/kg per day

**COMMENTS****Client Education**

- Recovery of function in distributions that lack nociception is unlikely.
- Physical rehabilitation may speed and enhance neurologic improvement.
- Some animals with TBPI will have chronic neuropathic pain.
- Those animals with neuropathic pain that self-mutilate or animals that have abrasions from dragging a limb will need to have wounds addressed by a veterinarian.
- Amputation is sometimes necessary if wounds can not be medically managed.

Patient Monitoring

- Many animals with TBPI will have other body systems or regions of the nervous system that may be injured. Careful physical examination is a must.

Possible Complications

- Animals with neuropathic pain may self-mutilate.
- Wound infection

Expected Course and Prognosis

- Prognosis is dependent on nociceptive status and whether lesions are complete or incomplete.
- Animals with absent nociception will be unlikely to recovery function in affected distributions.
- Animals with complete TBPI are likely to have a more protracted recovery than those with incomplete lesions.

Synonyms

- Brachial plexus avulsion is equivalent to complete TBPI.

Abbreviations

- CRI: constant rate infusion
- CT: computed tomography
- EMG: electromyography
- FCE: fibrocartilagenous embolic myelopathy
- IM: intramuscularly
- IV: intravenously
- MRI: magnetic resonance imaging
- NSAID: nonsteroidal anti-inflammatory drug
- PO: by mouth
- SQ: subcutaneously
- TBPI: traumatic brachial plexus injury

Suggested Reading

- Bailey, CS. Patterns of cutaneous anesthesia associated with brachial plexus avulsions in the dog. *J Am Vet Med Assoc* 1984;185:889–899.
- Griffiths, IR. Avulsion of the brachial plexus, 1: Neuropathology of the spinal cord and peripheral nerves. *J Small Anim Pract* 1974;15:165–176.
- Griffiths, IR, Duncan, ID, and Lawson, DD. Avulsion of the brachial plexus, 2: Clinical aspects. *J Small Anim Pract* 1974;15:177–182.
- Moissonnier, P, Duchossoy, Y, Lavieille, S, et al. Lateral approach of the dog brachial plexus for ventral nerve root reimplantation. *Spinal Cord* 1998;36:391–398.
- Wheeler, SJ, Clayton-Jones, DG, and Wright, JA. The diagnosis of brachial plexus disorders in dogs: a review of twenty-two cases. *J Small Anim Pract* 1986;27:147–157.

Author: Jonathan M. Levine

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Christine Berthelin-Baker

Bundle Branch Block—Left



DEFINITION/OVERVIEW

- Conduction delay or block in both the left posterior and left anterior fascicles of the left bundle
- A supraventricular impulse activates the right ventricle first through the right bundle branch; the left ventricle is activated late, causing the QRS to become wide and bizarre.

Electrocardiogram Features

- QRS prolonged; dogs, >0.08 sec, cats, >0.06 sec
- QRS wide and positive in leads I, II, III, and aVF
- Block can be intermittent or constant.



ETIOLOGY/PATHOPHYSIOLOGY

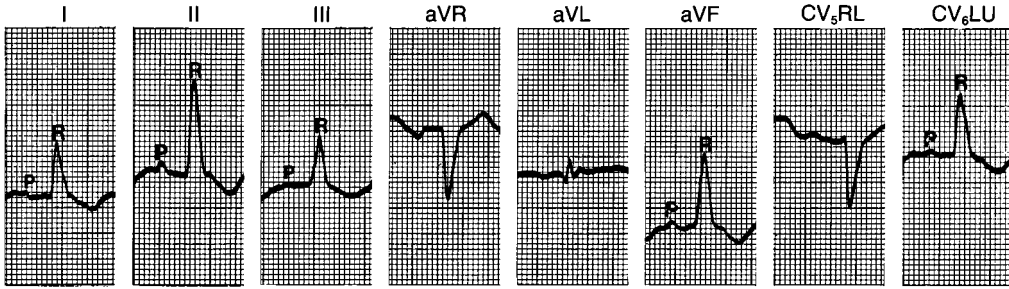
- Because the left bundle branch is thick and extensive, the lesion causing the block must be large.
- Usually an incidental ECG finding—does not cause hemodynamic abnormalities

Risk Factors/Causes

- Cardiomyopathy
- Direct or indirect cardiac trauma (e.g., hit by car and cardiac needle puncture)
- Neoplasia
- Subvalvular aortic stenosis
- Fibrosis
- Ischemic cardiomyopathy (e.g., arteriosclerosis of the coronary arteries, myocardial infarction, and myocardial hypertrophy that obstructs coronary arteries)

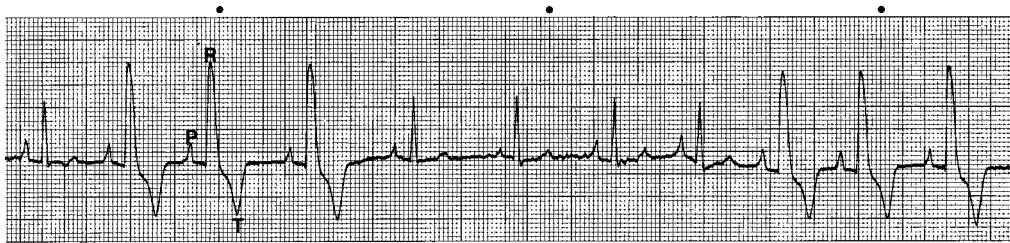
Systems Affected

- Cardiovascular



■ **Figure 14.1** Left bundle branch block in a cat with hypertrophic cardiomyopathy. The QRS complex is of 0.07-second duration and is positive in leads I, II, III, and aVF. Neither a Q wave nor an S wave occurs in these leads. The QRS complex is inverted in leads aVR.

Source: From: Tilley LP. *Essentials of Canine and Feline Electrocardiography*. 3rd ed. Blackwell Publishing, 1992, with permission.



■ **Figure 14.2** Intermittent left bundle branch block in a Chihuahua. QRS complexes are wider (0.07–0.08 seconds) in the second, third, and fourth complexes and in the last three complexes. Consistent P-R interval confirms a sinus origin for the abnormal appearing QRS complexes (lead II, 50 mm/sec, 1 cm 5 1 mV).

From: Tilley LP. *Essentials of Canine and Feline Electrocardiography*. 3rd ed. Blackwell Publishing, 1992, with permission.



SIGNALMENT/HISTORY

Species

- Cats and dogs

Historical Findings

- Usually an incidental ECG finding; does not cause hemodynamic abnormalities
- Signs usually associated with the underlying condition



CLINICAL FEATURES

- Does not cause signs or hemodynamic compromise.



DIFFERENTIAL DIAGNOSIS

- Left ventricular enlargement
- No left ventricular enlargement on thoracic radiograph or cardiac ultrasound studies supports diagnosis of isolated left bundle branch block.
- Can also be confused with ventricular ectopic beats, but the PR interval is usually constant and left bundle branch block has no pulse deficits



DIAGNOSTICS

Imaging

- Echocardiography may reveal structural heart disease; absence of left-sided heart enlargement supports a diagnosis of left bundle branch block.
- Thoracic and abdominal radiographs may show masses or pulmonary metastatic lesions.
- Traumatic injuries could result in localized or diffuse pulmonary densities.

Diagnostic Procedures

- Electrocardiography
- Long-term ambulatory monitoring (Holter) may reveal intermittent left bundle branch block.

Pathologic Findings

- Possible lesions or scarring on endocardial surface in the path of the bundle branches; applying Lugol's iodine to the endocardial surface within 2 hours postmortem enables clear visualization of the conduction system.



THERAPEUTICS

Drug(s) of Choice

- None, unless required for management of underlying condition

Diet

- No modifications unless required for management of underlying condition

Activity

- Unrestricted unless required for management of underlying condition

Appropriate Health Care

- Directed toward the underlying cause

Nursing Care

- Generally not necessary



COMMENTS

Client Education

- Left bundle branch block per se does not cause hemodynamic abnormalities.
- Lesion causing the block could progress, leading to more serious arrhythmias or complete heart block.

Patient Monitoring

- Serial ECG may show clearing or progression to complete heart block.

Possible Complications

- Causative lesion could progress, leading to a more serious arrhythmia or complete heart block.
- First- or second-degree AV block may indicate involvement of the right bundle branch.

Expected Course and Prognosis

- No hemodynamic compromise

Abbreviations

- AV: atrioventricular
- ECG: electrocardiogram
- AVF: arteriovenous fistula

See Also

- Atrioventricular (AV) Block

Suggested Reading

Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Ames, IA: Blackwell Publishing, 1992.

Tilley, LP, Smith, FWK, Oyama, M, and Sleeper, M. *Manual of Canine and Feline Cardiology*, 4th ed.. St. Louis: Saunders/Elsevier, 2008.

Author: Larry P. Tilley

Bundle Branch Block—Right

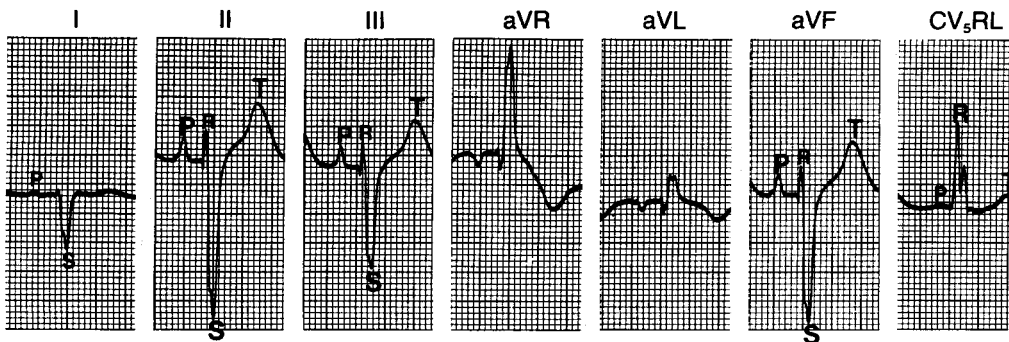


DEFINITION/OVERVIEW

- Conduction delay or block in the right bundle branch resulting in late activation of the right ventricle.
- The block can be complete or incomplete.

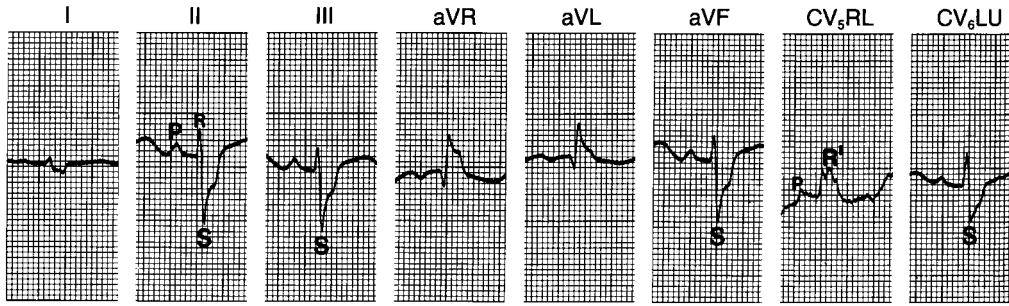
Electrocardiogram Features

- A right axis deviation and wide QRS (≥ 0.08 seconds in dogs; ≥ 0.06 seconds in cats) in most patients
- Large, wide S waves in leads I, II, III, and aVF (Figure 15.1 and 15.2)



■ **Figure 15.1** Right bundle branch block in a dog. The electrocardiographic features include QRS duration of 0.08 seconds; positive QRS complex in aVR, aVL, and CV₅RL (M shaped); and large wide S waves in leads I, II, III, and aVF. There is a right axis deviation (approximately -110°) (50 mm/sec, 1 cm 5 1 mV).

From: Tilley LP. *Essentials of Canine and Feline Electrocardiography*. 3rd ed. Blackwell Publishing, 1992, with permission.



■ **Figure 15.2** Right bundle branch block in a cat with the dilated form of cardiomyopathy. The QRS duration is 0.08 seconds (4 boxes). Large and wide S waves are present in leads I, II, III, aVF, and CV₆LU. The QRS in CV₅RL has a wide R wave (M-shaped). There is a marked axis deviation (approximately -90°).

Source: From: Tilley LP. *Essentials of Canine and Feline Electrocardiography*. 3rd ed. Blackwell Publishing, 1992, with permission.



ETIOLOGY/PATHOPHYSIOLOGY

- The right bundle branch is anatomically vulnerable to injury because it is a thin strand of tissue and has a long undivided course.
- No hemodynamic compromise

Risk Factors/Causes

- Occasionally seen in normal and healthy dogs and cats
- Congenital heart disease
- Chronic valvular fibrosis
- After surgical correction of a cardiac defect
- Trauma caused by cardiac needle puncture to obtain blood sample
- Trauma from other causes
- Chronic infection with *Trypanosoma cruzi* (Chagas' disease)
- Neoplasia
- Heartworm disease
- Acute thromboembolism
- Cardiomyopathy
- Hyperkalemia (most commonly in cats with urethral obstruction)

Systems Affected

- Cardiovascular



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predispositions

- In beagles, incomplete right bundle branch block can result from a genetically determined localized variation in right ventricular wall thickness.

Historical Findings

- Usually an incidental ECG finding—does not cause hemodynamic abnormalities
- Observed signs are usually associated with the underlying condition.



CLINICAL FEATURES

Physical Examination Findings

- Splitting of heart sounds because of asynchronous activation of ventricles in some patients
- Does not cause signs of hemodynamic compromise



DIFFERENTIAL DIAGNOSIS

- Right ventricular enlargement—absence of right ventricular enlargement on thoracic radiographs or echocardiogram supports a diagnosis of right bundle branch block.
- It can also be confused with ventricular ectopic beats (especially if the block is intermittent), but PR intervals are consistent and no pulse deficits with right bundle branch block.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- None specific
- Serum potassium may be extremely high in cats with urethral obstruction.

Other Laboratory Tests

- Occult heartworm test may be positive in dogs or cats.
- Chagas' indirect fluorescent antibody test, direct hemagglutination, and complement fixation test may be positive in dogs.

Imaging

- Echocardiogram may show structural heart disease; absence of right-sided heart enlargement supports the diagnosis.
- Thoracic and abdominal radiographs may show masses or pulmonary metastatic lesions; traumatic injuries could cause localized or diffuse pulmonary densities.

Diagnostic Procedures

- Electrocardiography
- Echocardiography

Pathologic Findings

- Possible lesions or scarring on endocardial surface in the path of the bundle branches; applying Lugol's iodine to the endocardial surface within 2 hours postmortem gives clear visualization of the conduction system.



THERAPEUTICS

Drug(s) of Choice

- None, unless needed to manage underlying condition

Diet

- No modifications unless required to manage underlying condition

Appropriate Nursing Care

- Direct treatment toward the underlying cause.



COMMENTS

Client Education

- Does not cause hemodynamic abnormalities itself
- The lesion causing the block could progress, leading to more serious arrhythmias or complete heart block.

Patient Monitoring

- Serial ECG may show resolution of the lesion or progression to complete heart block.

Possible Complications

- The causative lesion could progress, leading to a more serious dysrhythmia or complete heart block.
- First- or second-degree AV block may indicate involvement of the left bundle branch.

Expected Course and Prognosis

- No hemodynamic compromise

Abbreviations

- AV: atrioventricular
- ECG: electrocardiogram
- AVF: arteriovenous fistula

Suggested Reading

Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Ames, IA: Blackwell Publishing, 1992.

Tilley, LP, Smith, FWK, Oyama, M, and Sleeper, M. *Manual of Canine and Feline Cardiology*, 4th ed. St. Louis: Saunders/Elsevier, 2008.

Author: Larry P. Tilley

Canine Distemper



DEFINITION/OVERVIEW

- Canine distemper virus infection is among the most serious, contagious, systemic infections affecting dogs worldwide.
- In nature, the virus is found in a multitude of species. Because of its presence through many species, opportunity for eradication is minimal.
- Vaccination is highly effective and recommended for all dogs beginning at 6 to 8 weeks of age.



ETIOLOGY/PATHOPHYSIOLOGY

- Caused by an RNA virus of the genus *Morbillivirus*.
- Found in a wide range of carnivores, dogs serve as the principal reservoir for CDV and may be an important source of virus transmitted to wildlife.
- Viral shedding begins about 7 days post-infection and may be sustained for up to 60 to 90 days.
- Transmission occurs most commonly through infectious respiratory secretions but can be found in most tissues and other secretions of infected animals, including urine.
- Spontaneous infections are most likely to occur in puppies between 3 and 6 months of age.
- Subclinical infection is relatively common; therefore the prevalence of infection is higher than that of clinical disease. As a result, risk for infection is highest among puppies that: (a) have contact with other young dogs, (b) do not receive an initial vaccine series, and (c) are colostrum-deprived (i.e., fail to receive maternally derived antibody). (NOTE: protection afforded by maternally derived canine distemper antibody persists until about 9 to 12 weeks of age in puppies with a normal nursing history. Depending on the antibody titer of the bitch, the duration of protective immunity may be more or less than expected.)
- CDV can be isolated from most tissues/fluids of infected dogs, although epithelium and CNS tissues are preferentially targeted.
- Virus is widely disseminated throughout lymphoid tissues by 6 days post-infection; virus shedding occurs by 14 days post-infection, even in dogs with subclinical infection.

- Clinical consequences of CDV infection are largely defined by the degree and type of immune response the patient is able to mount.
- By 9 to 14 days post-infection, dogs that mount a poor immune response experience widespread dissemination of virus that involves the intestinal epithelium, exocrine and endocrine glands, respiratory tract, genitourinary tract, and even skin.
- Acute CDV encephalitis can follow hematogenous spread of virus into the CNS and is most likely to occur in young or immunosuppressed dogs.
- Acute CDV encephalitis is associated with a poor prognosis for recovery.
- CDV encephalitis also occurs as a subacute or chronic infection and is associated with reduced viral replication in the CNS, a relatively strong humoral immune response, and lack of lymphoid cell depletion.
- The ability of virus to persist in the CNS may be associated with what is now described as an uncommon consequence of infection, “old dog encephalitis” (ODE) or “old dog distemper”.
- Old dog encephalitis is a noncontagious variant of CDV infection that is associated with progressive inflammatory disease involving grey matter of the cerebral hemispheres and brainstem.
- Minor genetic variation of CDV has been recognized that may explain the variation in virulence seen in dogs. For example, the Snyder Hill strain of CDV is neurotropic and causes polioencephalomyelitis. Despite this variation, CDV isolates remain serologically homogeneous.



SIGNALMENT/HISTORY

- There is no age, breed, or gender predilection for CDV infection following exposure.
- Most infections do occur in puppies, particularly those that have not nursed, have an inadequate vaccination history, or have been group-housed with other dogs (e.g., shelters).
- Although transmission typically occurs following exposure to infectious respiratory secretions, neonatal infections can result following transplacental transmission of CDV.
- Affected puppies may be aborted, still-born, or weak at birth.
- Neurologic signs develop in affected neonates following transplacental exposure between 4 and 6 weeks of age, despite mild to inapparent signs in the bitch.

Historical Findings

- Owners of puppies with clinical signs caused by CDV report rapid onset of deterioration (days) in a previously healthy dog.
- Clinical signs of CDV can include lethargy, loss of appetite, vomiting, diarrhea, and thick (purulent) nasal/ocular discharge.



CLINICAL FEATURES

- Clinical signs of CDV infection are seldom pathognomonic during initial physical examination.
- Systemic signs range from mild (lethargy) to severe (seizures).
- The spectrum of acute onset clinical signs includes: fever, dehydration, purulent nasal and ocular discharge (Figure 16.1), cough, respiratory distress, conjunctivitis, vomiting, and diarrhea, which may be liquid in consistency and may contain frank blood or mucus.
- Dogs that survive acute systemic disease can develop a variety of clinical signs.
- Skin lesions include pustular dermatitis in puppies, nasal and digital (“hard pad”) hyperkeratosis, and juvenile cellulitis.
- Neurologic signs may develop as early as 1 to 3 weeks following recovery from systemic illness; onset of neurologic signs may be delayed for several weeks or months.
- Depending on the area of the CNS affected, signs include hyperesthesia or cervical rigidity (meningitis), seizures, vestibular signs, ataxia, paresis, and myoclonus (involuntary muscle twitching).
- Bone lesions have been associated with CDV infection in large-breed dogs between 3 and 6 months of age. Long bone lesions consistent with HOD have been associated with CDV infection and with administration of modified-live virus vaccine.
- Ocular lesions associated with CDV infection may develop after recovery from acute systemic disease and include sudden blindness and persistent mydriasis (optic neuritis), retinal detachment, inactive, circumscribed areas of retinal hyper-reflectivity (“gold medallion lesions”), and keratoconjunctivitis sicca (“dry eye”).



■ **Figure 16.1** Conjunctivitis, rhinitis, and facial dermatitis in a 2-year-old, unvaccinated, moribund dog at presentation; acute canine distemper was confirmed.



■ **Figure 16.2** Enamel hypoplasia in a young dog that recovered from canine distemper virus infection.

- Enamel hypoplasia, occasionally seen in adult dogs, is evidence of prior CDV infection (Figure 16.2).



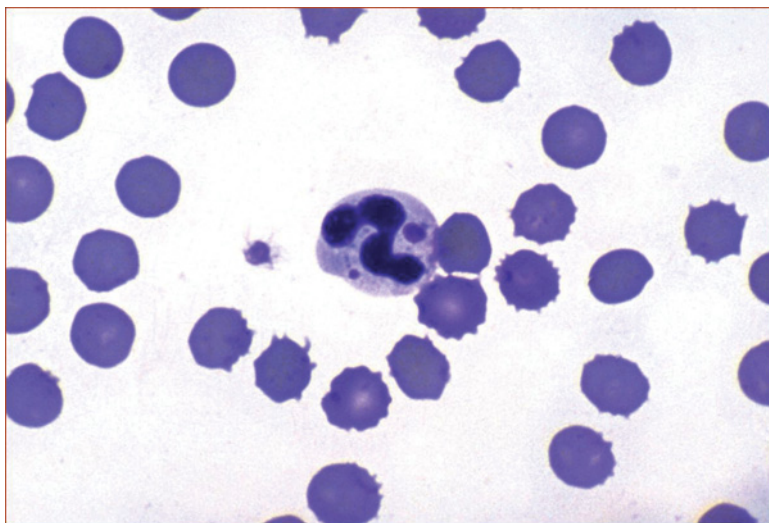
DIFFERENTIAL DIAGNOSIS

- Because of the wide spectrum of tissues affected, dogs with CDV infection are difficult to identify on the basis of clinical signs alone.
- Canine infectious tracheobronchitis is a common differential diagnosis for CDV infection in dogs of any age, particularly in non-vaccinates.
- Because of the prevalence of neurologic signs associated with CDV infection and the predilection for disease to develop in nonvaccinated puppies, rabies must be considered a principal differential diagnosis.



DIAGNOSTICS

- Clinical signs of systemic illness consistent with distemper can lead to a presumptive diagnosis in puppies 3 to 6 months of age.
- Confirmation of CDV infection is more problematic, especially in adult dogs.
- Routine hematology and biochemistry panels may reflect the degree of systemic illness but are not diagnostic for CDV infection.
- Examination of peripheral blood smears or exfoliative cytology (e.g., conjunctival scrapings) for intracellular distemper inclusion bodies is highly diagnostic, particularly in the early stages of infection (Figure 16.3). (NOTE: use of a quick Romanowsky-type stain is recommended over conventional Wright-Giemsa stains for elucidating distemper inclusions).



■ **Figure 16.3** Dark blue-staining distemper virus inclusion body within the cytoplasm of a neutrophil (at the 2 o'clock position) of an unvaccinated dog with acute distemper; slide was stained with a commercial Diff-Quik stain (recommended) to elucidate inclusion bodies.

- Detection of elevated levels of distemper-specific IgG in CSF is diagnostic of infection. Distemper vaccination does not cause increased levels of CSF antibody. Detection of elevated levels of distemper-specific IgG in serum (virus neutralization), however, is indicative of protection but is not diagnostic of infection.
- Although availability is limited, advanced diagnostic techniques such as immunohistochemistry and detection of CDV RNA in whole blood, serum, and CSF can be used for antemortem diagnosis of distemper.

Pathologic Findings

- A wide range of postmortem findings are described in dogs that die from CDV infection.
- Common gross lesions include pneumonia, catarrhal enteritis, and evidence of rhinitis, conjunctivitis, and tracheobronchitis. Gross CNS lesions are uncommon.
- Histopathology of CNS tissue demonstrates encephalitis and neuronal demyelination with or without perivascular inflammation.
- CDV inclusions are typically found in epithelium of mucous membranes and urinary bladder, leukocytes, and neurons from 5 to 6 weeks post-infection.



THERAPEUTICS

- Treatment is limited to supportive therapy intended to reduce mortality.
- Dogs with advanced CNS signs have a poor prognosis for recovery; recommendation for euthanasia may be justified.

- Supportive care typically includes oral or intravenous antimicrobials, fluid replacement, and analgesics.
- Treatment options for neurologic signs are limited and less likely to be effective.



COMMENTS

Client Education

- Clients who have experienced canine distemper infection in a pet should understand the importance of administering distemper vaccination prior to bringing the new dog into the environment, especially if it has been less than 1 month from the time of diagnosis or death.
- CDV does not reside in the environment for extended periods and common disinfectants are effective in killing virus.
- Dogs that recover from the acute systemic illness may shed CDV for 1 to 2 weeks and therefore pose a significant risk to susceptible dogs.

Prevention/Avoidance

- Vaccination of all dogs against CDV is recommended.
- Two vaccine types are available: MLV and rCDV. There are no killed CDV vaccines.
- Current (revised) vaccination recommendations stipulate that puppies should receive a dose of CDV (usually in combination with parvovirus and adenovirus-2) at 3- to 4-week intervals beginning as early as 6 weeks of age and ending not earlier than 15 to 16 weeks of age regardless of the product used.
- All dogs should be revaccinated 1 year following administration of the last dose in the initial series. All commercial vaccines provide sustained immunity that lasts several years; vaccination of adult dogs every 3 years is recommended.
- In high-exposure risk environments and in the face of an outbreak (e.g., shelters), early vaccination beginning at 3 weeks of age, and every 2 weeks thereafter, is indicated until 15 to 16 weeks of age.
- Maternal antibody interference of vaccine is the most common cause of immunization failure when using MLV CDV vaccine.
- Recombinant distemper (rDistemper) vaccine has been shown to immunize puppies in the face of maternal antibody and may provide a significant advantage over MLV vaccines in high-risk environments.

Abbreviations

- CDV: canine distemper virus
- CNS: central nervous system
- CSF: cerebrospinal fluid
- HOD: hypertrophic osteodystrophy

- IgG: immunoglobulin G
- MLV: modified-live virus
- rCDV: recombinant canine distemper virus
- RNA: ribonucleic acid

Suggested Reading

Chappuis, G. Control of canine distemper. *Vet Microbiol* 1995;44:351–358.

Ford, RB. All vaccines are not alike: the benefits of recombinant technology. *Supplement Compend Cont Ed Sm Anim Pract* 2009;31:3–6.

Greene, CE, and Appel, MJ. Canine distemper. In: Greene, CE, ed. *Infectious Diseases of the Dog and Cat*, 3rd ed., p. 25. St. Louis: Saunders-Elsevier, 2006.

Larson, LJ, and Schultz, RD. Effect of vaccination with recombinant canine distemper virus vaccine immediately before exposure under shelter-like conditions. *Vet Therapeutics* 2006;7:113–118.

Paul, MA, Carmichael, LE, Childers, H, et al. 2006 AAHA Canine Vaccine Guidelines (revised February 2007). Full text and references available at: www.aahanet.org/PublicDocuments/VaccineGuidelines06Revised.pdf; accessed January 2009.

Author: Richard B. Ford

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Max J.G. Appel

Canine Parvoviral Enteritis



DEFINITION/OVERVIEW

- CPV is a highly contagious disease of immature and poorly vaccinated dogs.
- CPV affects the GI tract and lymphoid tissues, and if left untreated, is associated with high morbidity and mortality.



ETIOLOGY/PATHOPHYSIOLOGY

- Infection occurs by fecal-oral transmission.
- Incubation period ranges from 3 to 8 days.
- The virus initially replicates in the lymphoid tissues of the oropharynx, then subsequently spreads via the bloodstream to rapidly dividing cells of the GI tract, other lymphoid tissues (mesenteric lymph nodes, spleen, thymus) and bone marrow.
- CPV affects the germinal epithelium of the intestinal crypts, and results in destruction of epithelium and impaired normal cell turnover. This, in turn, results in villous atrophy and sloughing. Bacterial translocation, bacteremia, and endotoxemia are common sequelae of the impaired GI mucosal barrier.
- Bone marrow involvement results in leukopenia that is characterized by lymphopenia and neutropenia.

Systems Affected

- GI—vomiting and diarrhea are consequences of destruction of the intestinal crypt epithelium.
- Hemic/Lymphatic/Immune—leukopenia occurs secondary to bone marrow involvement.
- Cardiovascular—rapidly worsening dehydration may progress to signs of shock and cardiovascular collapse due to large fluid losses.



SIGNALMENT/HISTORY

- Signs and observations often reported by the owner include lethargy, anorexia, vomiting, and brown or hemorrhagic diarrhea.

Risk Factors/Causes

- Overcrowded and unsanitary conditions, intestinal parasitism and lack of protective immunity.
- Any breed may be affected, but the following breeds are at increased risk:
 - American pit bull terrier, Doberman pinscher, Rottweiler, Labrador retriever, and German shepherd dog. It is not apparent whether a genetic predisposition exists, as opposed to breed popularity or increased proportion of unvaccinated dogs in these breeds.
- Puppies between 6 weeks and 6 months of age are most commonly affected. In dogs older than 6 months of age, intact males are twice as likely to acquire CPV infection as intact females.



CLINICAL FEATURES

- Depression/lethargy (Figure 17.1).
- Fever
- Dehydration characterized by tacky mucous membranes, prolonged skin tent, sunken eyes. Frequently, dehydration may progress to clinical signs of shock that include poor pulse quality, tachycardia, tachypnea, prolonged CRT, cool extremities.
- Painful abdomen; a mass effect may be palpable if intussusception is present.



■ **Figure 17.1** Profound lethargy is a frequently diagnosed clinical sign in canine parvoviral infections.



DIFFERENTIAL DIAGNOSIS

- Other infectious diseases
 - Bacterial—*Campylobacter*, *Salmonella*, *Clostridium*
 - Viral—coronavirus, CDV
- Severe parasitic or protozoal infestation—*Giardia*, *Coccidia*, *Cryptosporidium*, roundworms, hookworms, whipworms
- Foreign body or intussusception
- Dietary indiscretion
- Toxin ingestion
- Metabolic diseases—hepatic, renal, hypoadrenocorticism
- Pancreatitis
- Central nervous system disease



DIAGNOSTICS

- Fecal ELISA antigen test is a practical cage-side test that has good sensitivity and specificity (Figure 17.2).
 - False-positives may occur within 5 to 12 days of administration of an attenuated vaccine.
 - False-negative results may be seen due to a short period of fecal CPV shedding.



■ **Figure 17.2** Fecal antigen enzyme-linked immunosorbent assay (ELISA) is a quick and convenient bedside diagnostic test for canine parvovirus infections.

- Fecal PCR—highly sensitive and specific; can aid in distinguishing between a vaccine and virulent strains of CPV; is not routinely commercially available.
- Serology—positive results are not diagnostic for an active CPV infection, as 25 to 90 percent of healthy animals may be seropositive secondary to a previous subclinical infection. Detection of IgM antibodies combined with suggestive clinical signs is necessary for diagnosis.
- Immunochemistry, latex agglutination, viral isolation, and electron microscopy may be used to demonstrate virus in tissue culture, feces, or tissues. These tests require specialized diagnostic laboratories.

Pathologic Findings

- Gross findings: thickening and segmental discoloration of distal duodenum, jejunum and ileum; denudation of intestinal mucosa; abdominal lymphadenopathy.
- Microscopic findings: shortening and obliteration of intestinal villi; crypt epithelial necrosis; necrosis of lymphoid tissues (spleen, thymus, Peyer's patches, mesenteric lymph nodes); viral intranuclear inclusion bodies may be visualized in epithelium of the GI tract.



THERAPEUTICS

- The objectives of treatment are correction of dehydration or shock, restoration of fluid and electrolyte balance, prevention or treatment of secondary bacterial infection, and aggressive supportive care while the GI tract is recovering.
- Intravenous fluid administration is the mainstay of therapy of CPV infections. High fluid rates are frequently required because of severe fluid depletion and significant ongoing losses in form of vomiting and diarrhea. If an animal is in shock, an initial fluid bolus of 20 to 30 ml/kg of a balanced isotonic crystalloid solution over 15 to 30 minutes is indicated, followed by reassessment of perfusion parameters (i.e., heart rate, CRT, blood pressure) to determine if additional fluid resuscitation is required. The goal of resuscitation is return to normal hemodynamic parameters (i.e., blood pressure, mucous membrane color, CRT, heart rate). If an intravenous fluid bolus is not required or after it has been completed, the fluid rate may be determined by approximating the animal's fluid deficit (percent dehydration \times body weight [kg]) and replacing it over 12 to 24 hours, adding on maintenance needs (2–4 ml/kg per hour) and ongoing fluid losses; typical fluid rates average ~10 ml/kg per hour.
- If crystalloid solutions fail to restore perfusion, if total protein levels decrease to below 4 g/dl, or if a patient develops signs of peripheral edema, synthetic colloids are indicated. A 3 to 5 ml/kg bolus may be given to an animal in shock; alternatively, an infusion at the rate of 1 ml/kg per hour may be administered if a bolus is not indicated. Traditionally, a total dose of colloids should not exceed 20 to 30 ml/kg per day; however, in patients that are critically ill that require very high fluid rates this limit may be exceeded, if necessary.

Drug(s) of Choice

Antibiotics

- Indicated due to destruction of the GI mucosal barrier and high potential for bacterial translocation, as well as leukopenia, which may predispose the animal to secondary bacterial infections
- Combination therapy may be used to provide broad-spectrum coverage: beta lactam (ampicillin 22 mg/kg IV, SQ every 6–8 hours) and fluoroquinolone (enrofloxacin IV, SQ 10–15 mg/kg every 24 hours) or aminoglycoside (gentamicin 6.6 mg/kg IV, SQ every 24 hours); see Precautions/Interactions.
- Single agent broad-spectrum antibiotics may be used, such as cefoxitin (15–30 mg/kg IV, SQ every 6 hours) or ampicillin/sulbactam (22 mg/kg IV, SQ every 8 hours)

Anti-Emetics

- If vomiting or nausea persists, antiemetic therapy is indicated. The following medications may also be used alone or in combination with each other:
 - Serotonin antagonists (dolasetron 0.5–1 mg/kg every 12–24 hours)
 - Maripotent (1 mg/kg SQ every 24 hours for 5 days); not approved for use in dogs under 16 weeks.
 - Phenothiazine derivatives (chlorpromazine 0.1–0.5 mg/kg IM, SQ every 8–12 hours); see Precautions/Interactions.
 - Metoclopramide—intermittent injections (0.1–0.4 mg/kg SQ every 6 hours), an intravenous CRI constant rate infusion (1–2 mg/kg per day); see Precautions/Interactions.

Pain Medications

- As some animals with CPV infections may exhibit significant abdominal pain, pain management is a useful adjunct to therapy. Opioid medications may be used, such as buprenorphine (0.01–0.02 mg/kg IV, IM, SQ every 6–8 hours), hydromorphone (0.1 mg/kg SQ, IM, IV every 6–8 hours), fentanyl (3–10 µg/kg per hour IV CRI); see Precautions/Interactions.

Supplements

- Patients with CPV infections are frequently hypokalemic because of the GI tract losses, as well as hypoglycemic because of decreased storage abilities and lack of oral food intake; potassium (maximum rate of 0.5 mEq/kg per hour) and glucose (2.5–5% added to intravenous fluids) often require supplementation.

Precautions/Interactions

- One of the adverse effects of aminoglycosides is nephrotoxicity, which could be exacerbated by dehydration or hypovolemia. These agents should not be administered to dehydrated patients; hydration should be restored prior to initiation of

therapy. If these drugs are used, daily urine sediment examinations should be performed to look for casts; therapy should be discontinued if casts are visualized.

- Fluoroquinolones should be used with caution in immature dogs because cartilage abnormalities have been associated with their administration.
- Phenothiazine derivative medications cause vasodilation and sedation, which may potentiate hypotension in animals with suboptimal perfusion and increase the chance of aspiration of GI contents in vomiting animals.
- Sedation may also be a side effect of opioid medications.
- Anticholinergic agents should not be administered because they may increase the potential for intestinal ileus and intussusception.
- Prokinetics, such as metoclopramide, are contraindicated in animals with high suspicion of GI obstruction, as there could be an increased risk of GI rupture.

Alternative Drugs

- Oseltamivir has been advocated for use in CPV infection. Despite certain favorable trends, it has not been shown to make a significant difference in management of CPV.
- FFP may be beneficial, as it provides immunoglobulins, as well as serum protease inhibitors to aid in neutralizing the virus and combat associated inflammation. In dogs suffering from coagulopathy due to DIC, FFP will provide coagulation factors as well.

Diet

- Oral intake should be discontinued in vomiting patients with CPV infection until vomiting is significantly reduced to absent. To reinitiate oral intake, small amounts of water should be offered and if tolerated, followed by frequent small meals of highly digestible low fiber, low fat diet.
- Early enteral nutrition has been advocated in CPV infections and is associated with earlier clinical improvement and significant weight gain; this can be achieved by placing a feeding tube, if a patient is anorexic. Trickle feeding small amounts of enteral nutrition has been shown to decrease patient morbidity and mortality, even in the face of vomiting.
- In severely affected animals, parenteral nutrition may be life-saving.

Activity

- No activity restrictions are necessary during or after recovery from CPV infection.
- The virus can be shed in the animal's feces for 14 to 30 days, so the animal and its feces should be isolated from other animals during this potentially infective time period.

Surgical Considerations

- Patients with CPV infection who develop an intussusception require emergency surgery; these patients may be at higher risk of developing perioperative complications due to their immunocompromised state. Fluid resuscitation is essential in dehydrated and hypovolemic dogs prior to surgery.



COMMENTS

Client Education

- Other immature or poorly vaccinated dogs in the household are susceptible to CPV infection; they should be evaluated by a veterinarian and vaccinated as soon as possible.
- The household, premises and any other objects that the affected animal has come into contact with should be disinfected with 1:30 dilution of bleach.
- CPV is ubiquitous and can survive in the environment for 5 months or longer, therefore owners should avoid obtaining a new puppy for at least 6 months.
- Convalescing animals typically shed large amounts of virus for up to 2 weeks after resolution of infection and, therefore, should be isolated for that period of time.
- Even though immunity to CPV infection is long lasting and possibly lifelong, it is imperative that the animal is vaccinated for other infectious diseases after recovery.

Patient Monitoring

- Frequent monitoring is essential to help guide therapeutic decisions. Physical parameters (i.e., temperature, mucous membrane color, CRT, heart rate, pulse quality, degree of abdominal pain) and blood pressure should be checked four to six times daily, as indicated.
- Packed red blood cell volume, total solids, and blood glucose should ideally be monitored at least twice daily. Electrolytes, acid-base status, and weight should be monitored at least once daily.

Prevention/Avoidance

- Attenuated live vaccine is the method of choice for prevention of CPV infection. Vaccination should be initiated at 6 to 8 weeks of age and repeated every 2 to 3 weeks until 16 to 18 weeks of age. In high-risk breeds, evaluation of CPV titers may be useful in ensuring appropriate level of protection. Maternal antibody interference is considered the biggest cause of vaccine failure; use of high-titer vaccines minimizes the chances of failure and is the current preferred vaccine.

Possible Complications

- Aspiration pneumonia due to vomiting; septic shock secondary to GI bacterial translocation and leukopenia; thromboembolism due to a hypercoagulable state, which may be followed by hypocoagulability.

Expected Course and Prognosis

- Average recovery time is 6 days.
- Prognosis for survival in animals that receive aggressive supportive care early in the course of disease is good to excellent; poor without treatment; and poor to guarded with outpatient care.

Synonyms

- Parvo

Abbreviations

- CDV: canine distemper virus
- CPV: canine parvovirus
- CRI: constant rate infusion
- CRT: capillary refill time
- DIC: disseminated intravascular coagulation
- ELISA: enzyme-linked immunosorbent assay
- FFP: fresh frozen plasma
- GI: gastrointestinal
- IgM: immunoglobulin M
- IM: intramuscularly
- IV: intravenously
- PCR: polymerase chain reaction
- SQ: subcutaneously

See Also

- Shock—Hypovolemic

Suggested Reading

- Hoskins, JD. Canine viral enteritis. In: Greene, CE, ed., *Infectious Diseases of the Dog and Cat*, 3rd ed., pp. 63–73. Philadelphia: WB Saunders, 2006.
- Macintire, DK, and Smith-Carr, S. Canine parvovirus. Part II. Clinical signs, diagnosis, and treatment. *Compend Contin Educ Pract Vet* 1997;19:291–300.
- Mohr, AJ, Leisewitz, AL, Jacobson, LS, Steiner, JM, Ruaux, CG, and Williams, DA. Effect of early enteral nutrition on intestinal permeability, intestinal protein loss, and outcome in dogs with severe parvoviral enteritis. *J Vet Int Med* 2003;17(6):791–798.
- Pollock, RV, and Coyne, MJ. Canine parvovirus. *Vet Clin North Am Small Anim Pract* 1993;23(3):555–568.
- Prittie, J. Canine parvoviral enteritis: a review of diagnosis, management, and prevention. *J Vet Emerg Crit Care* 2004;14(3):167–176.
- Sherding, RG. Intestinal viruses. In: Birschard, SJ, and Sherding, RG, eds. *Saunders Manual of Small Animal Practice*, 2nd ed., pp. 110–116. Philadelphia: WB Saunders, 2000.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Jo Ann Morrison

Cardiopulmonary Arrest (CPA) and Cardiopulmonary Cerebral Resuscitation (CPCR)



DEFINITION/OVERVIEW

- Cessation of effective perfusion and ventilation due to the absence of coordinated cardiac and respiratory function. Cardiac arrest invariably follows respiratory arrest if not recognized and corrected.



PATHOPHYSIOLOGY/ETIOLOGY

- Generalized or cellular hypoxia may be the cause or effect of sudden death.
- After 1 to 4 minutes of airway obstruction, breathing efforts stop while circulation remains intact.
- If obstruction continues for 6 to 9 minutes, severe hypotension and bradycardia lead to dilated pupils, absence of heart sounds, and lack of palpable pulse.
- After 6 to 9 minutes, myocardial contractions cease even though the ECG may look normal (PEA; also known as EMD).
- Ventricular fibrillation, ventricular asystole, and PEA are rhythms indicating cessation of myocardial function.

Systems Affected

- All systems are affected, but those requiring the greatest supply of oxygen and nutrients are affected first.
- Cardiovascular
- Renal
- Neurologic



SIGNALMENT/HISTORY

- Any age, breed, or sex.

Signs

- Loss of consciousness
- Dilated pupils

- Cyanosis
- Agonal gasping or absence of ventilation
- Absence of peripheral pulses
- Hypothermia
- Absence of auscultable heart sounds
- Lack of response to stimulation

Risk Factors/Causes

- Cardiovascular disease
- Respiratory disease
- Trauma
- Anesthesia
- Septicemia
- Endotoxemia
- Ventricular dysrhythmias (ventricular tachycardia, R on T phenomenon, multiform)
- Increased parasympathetic tone (gastrointestinal disease, respiratory disease, manipulation of eyes, larynx, or abdominal viscera)
- Prolonged seizures
- Invasive cardiovascular manipulation (pericardiocentesis, surgery, angiography)
- Hypoxemia caused by ventilation-perfusion mismatch, diffusion barrier impairment, hypoventilation, or shunting
- Poor oxygen delivery due to anemia or vasoconstriction
- Myocardial disease—infectious, inflammatory, infiltrative, traumatic, neoplastic, or embolic
- Acid-base abnormalities
- Electrolyte derangements—hyperkalemia, hypocalcemia, and hypomagnesemia
- Hypovolemia
- Shock
- Anesthetic agents
- Toxemia
- CNS trauma
- Electrical shock



DIFFERENTIAL DIAGNOSIS

- Severe hypovolemia and absence of palpable pulses
- Pericardial effusion, decreased cardiac output, and muffled heart sounds
- Pleural effusion with respiratory arrest
- Respiratory arrest can be confused with CPA.
- Upper airway obstruction can rapidly progress to CPA.



DIAGNOSTICS

- Sudden cardiovascular collapse associated with inadequate cardiac output can lead to severe consequences.
- Quick assessment and diagnosis are critical.
- Assess the ABCs: airway, breathing, and circulation.

Complete Blood Count/Biochemistry/Urinalysis

- May be beneficial in identifying an underlying or contributing cause to CPA but should not be part of initial triage of patient

Other Laboratory Tests

- Blood gas evaluation may be useful during or after resuscitative procedures but again is not part of initial emergency management
- Venous blood gas analysis may be more beneficial during resuscitation than arterial blood gas

Imaging

- Thoracic radiographs may help identify underlying disease processes but should only be considered when the patient has been stabilized.
- Echocardiography may confirm pericardial effusion or underlying myocardial disease but should not interfere with resuscitative procedures.

Diagnostic Procedures

- Once CPA has developed continuous ECG monitoring, blood pressure monitoring, pulse oximetry, and capnography may be useful in monitoring effectiveness of resuscitative procedures



THERAPEUTICS

- CPCR should be instituted immediately upon diagnosing CPA. CPCR can be divided into basic life support and advanced life support.

Basic Life Support

A: Airway

- Assessment: The airway should be visualized by extending the patient's head and neck and pulling the tongue forward. Any debris such as secretions, blood, or vomitus should be cleared manually or with suction.



■ **Figure 18.1** Placement of a needle through the nasal philtrum to the level of the periosteum in an attempt to stimulate spontaneous respiration.

- **Establish:** An airway should be established either via per oral endotracheal intubation or if complete obstruction exists, emergency tracheotomy.

B: Breathing

- **Assessment:** Make sure animal is not breathing.
- **Institute artificial ventilation:** Administer two short breaths approximately 2 seconds duration each and reassess. If spontaneous respiration does not occur, continue ventilations at a rate suitable for this animal (normal respiratory rate). Techniques for ventilation include mouth to mouth, mouth to nose, or mouth to endotracheal tube. These techniques provide approximately 16 percent oxygen. The use of an Ambu bag and room air provides 21 percent oxygen.
- The preferred technique is endotracheal intubation and ventilation with 100 percent oxygen using an Ambu bag or an anesthesia machine. The suggested rate of oxygen administration is 150 ml/kg per minute.
- The “Gen Chung” maneuver involves placement of a needle through the point of the nasal philtrum to the level of the periosteum and twisting. The stimulus can aid in re-establishing spontaneous respiration (Figure 18.1).

C: Circulation

- **Assessment:** Palpate peripheral pulses and auscultate heart to confirm CPA.
- External cardiac massage has been shown to provide, at best, about 30 percent of normal cardiac output. Internal cardiac massage has been shown to be two to three times more effective in improving cerebral and coronary perfusion.

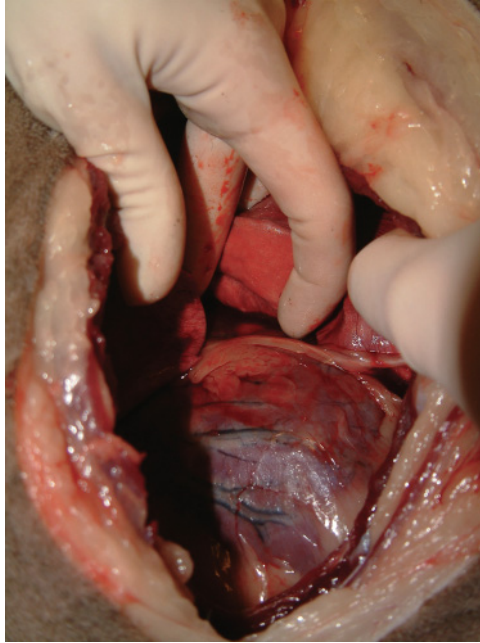


■ **Figure 18.2** Demonstration of the thoracic pump, in which compressions are placed over the widest portion of the thorax. In this image, an assistant is also performing interposed abdominal compressions to help push blood back into the thoracic vena cava and the right-sided heart during the time when the thorax is not compressed.

- Hemodynamic studies in animal models suggest that several different mechanisms exist for the generation of blood flow (artificial systole) during chest compressions. During external cardiac massage the cardiac pump theory takes advantage of direct compression of the heart in animals less than 7 kilograms. In animals larger than 7 kilograms, the thoracic pump theory is utilized. This technique utilizes increases in intrathoracic pressures to increase cardiac output via the major arteries.

Compression/Ventilation Techniques

- Chest compressions should be performed rapidly at a rate of between 80 and 100 compressions per minute. The chest should be displaced approximately 30 percent.
- Recent information suggests that compressions performed to the music “Staying Alive” provides a compression rate of approximately 100 compressions per minute.
- In animals less than 7-kg body weight, the cardiac pump mechanism should be utilized. With the animal in right lateral recumbency compressions are performed directly over the heart (intercostal spaces 3–5). This can be done using one hand or two hands.
- In animals larger than 7-kg body weight, the thoracic pump mechanism should be utilized. With the animal in right lateral, thoracic compressions are applied at the widest portion of the thorax (Figure 18.2).
- If using asynchronous ventilation and compression, one breath is given following every five compressions.
- If using synchronous ventilation and compression, one breath is given simultaneously with every fourth to fifth compression.



■ **Figure 18.3** The heart within the pericardial sac during open-chest cardiopulmonary chest resuscitation. Visualize the phrenic nerve over the dorsal portion of the pericardium and avoid damage to the phrenic nerve by incising the pericardium at the apex of the heart, then ripping the pericardium with your fingers until the heart can be extracted from the pericardial sac for direct cardiac compressions.

- Interposed abdominal compressions between chest compressions have been shown to enhance cerebral and coronary blood flow by increasing aortic diastolic pressure.

Open-Chest Cardiopulmonary Cerebral Resuscitation

- Indicated if closed chest CPR is ineffective or pre-existing conditions such as flail chest, obesity, diaphragmatic hernia, pericardial effusion, and so on preclude effective closed chest techniques
- Performed through a left thoracotomy at the fifth or sixth intercostal space (Figure 18.3)
- A pericardectomy should be performed.
- The palmar surface of the fingers and thumb are used to milk the ventricular blood toward the great vessels. Digital compression of the descending aorta may help cranial perfusion.

Advanced Life Support

D: Drugs

- Drug selection is based on the arrhythmia that is present.
- Atropine and epinephrine are most often correct selections.

E: Electrocardiogram

- Accurate ECG interpretation is imperative.
- Try to minimize cessation of thoracic compressions when evaluating ECG.

F: Fibrillation Controls and Fluids

- Defibrillation is time dependent and must be performed immediately.
- Fluids should be administered cautiously.
- Aggressive volume resuscitation should not be used unless hypovolemia was thought to be a contributing factor in CPA.
- Volume overload can lead to decreased coronary artery perfusion, therefore, intravenous fluids are contraindicated unless relative (i.e., sepsis or anesthetic gases) or absolute (i.e., hemorrhage, severe volume loss due to vomiting, diarrhea, or wound exudates) hypovolemia is present.

Drug(s) of Choice

- The selection of drugs is based on the arrhythmia present.
- Epinephrine: 0.01 mg/kg IV repeated every 3 to 5 minutes.
- Atropine: 0.05 mg/kg IV repeated every 3 to 5 minutes for maximum of three doses.
- Vasopressin: 0.8 U/kg IV; may be used in refractory cases.
- Drugs should be administered via central vein, intratracheal, intraosseous, or peripheral vein in descending order of preference. Intratracheal administration requires double the calculated volume to be delivered. Sodium bicarbonate should *never* be administered into the trachea.
- Intracardiac drug administration should be used as a last resort only, unless open chest CPCR is being performed and drugs can be administered directly into the left ventricle. Blind thoracocentesis in an attempt to perform an intracardiac injection is *contraindicated*, as injection directly into the myocardium or damage to the coronary arteries can occur.

**COMMENTS****Miscellaneous****Comparative Cardiopulmonary Cerebral Resuscitation**

- Current recommendations of the American Heart Association include defibrillation as a component of basic life support. This has not been extrapolated to veterinary patients. The most common rhythm associated with cardiac arrest in humans is ventricular fibrillation, whereas the most common rhythm in veterinary patients that leads to cardiac arrest is PEA.

Patient Monitoring

- Maintain heart rate and blood pressure with fluids and inotropic agents.
- Monitor arterial blood pressure.
- Monitor central venous pressure.
- Blood gas analysis.
- Support respiration with artificial ventilation and supplemental oxygen.
- Continued neurological assessment. If signs of increased intracranial pressure, consider mannitol and furosemide.
- Continued monitoring of ECG.
- Monitor urine output.
- Monitor body temperature.
- Radiograph thorax to assess resuscitative injury such as rib fractures or pulmonary contusions. Noncardiogenic pulmonary edema can occur secondary to airway obstruction.
- Diagnose and correct factors that lead to initial CPA.

Possible Complications

- Vomiting
- Aspiration pneumonia
- Fractured ribs or sternebrae
- Pulmonary contusions and edema
- Pneumothorax
- Acute renal failure
- Neurologic deficits
- Cardiac dysrhythmias

Expected Course and Prognosis

- Prognosis is dependent on underlying disease process.
- Rapid return to spontaneous cardiac and respiratory function improves prognosis.
- Overall prognosis is poor with less than 10 percent of patients being discharged.

Synonyms

- Cardiac arrest
- Heart attack

Abbreviations

- CNS: central nervous system
- CPA: cardiopulmonary arrest
- CPR: cardiopulmonary cerebral resuscitation
- ECG: electrocardiogram
- EMD: electrical-mechanical dissociation

- IV: intravenously
- PEA: pulseless electrical activity

Suggested Reading

- Cole, SG, Otto, CM, and Hughes, D. Cardiopulmonary cerebral resuscitation in small animal—a clinical practice review (Part I). *J Vet Emerg Crit Care* 2002;12:261–267.
- Cole, SG, Otto, CM, and Hughes, D. Cardiopulmonary cerebral resuscitation in small animal—a clinical practice review (Part II). *J Vet Emerg Crit Care* 2003;13:13–23.
- ECC Committee, Subcommittees and Task Force of the American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation* 2005;112(24) Supplement.
- Haldane, S, and Marks, SL. Cardiopulmonary cerebral resuscitation: Techniques (Part 1). *Comp Cont Ed Pract Vet* 2004;26:780–790.
- Haldane, S, and Marks, SL. Cardiopulmonary cerebral resuscitation: Emergency drugs and postresuscitative care (Part 2). *Comp Cont Ed Pract Vet* 2004;26:791–799.
- Waldrop, JE, and Rozanski, EA, et al. Causes of cardiopulmonary arrest, resuscitation management, and functional outcome in dogs and cats surviving cardiopulmonary arrest. *J Vet Emerg Crit Care* 2004;14(1):22–29.

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Chocolate Toxicity



DEFINITION/OVERVIEW

- Ingestion of chocolate (methylxanthine alkaloids) in sufficient quantity to cause gastrointestinal, neurologic, and cardiac abnormalities



ETIOLOGY/PATHOPHYSIOLOGY

- Methylxanthine alkaloids—theobromine and caffeine from the cocoa bean
- Methylxanthines—adenosine receptor antagonist in the CNS; causing stimulation and cerebral vasoconstriction; direct myocardial stimulator—tachycardia; increased calcium entry into the sarcoplasmic reticulum—increased skeletal and myocardial contractility
- Caffeine—phosphodiesterase inhibitor; increased cAMP and the release of catecholamines
- Theobromine—undergoes enterohepatic recirculation (Table 19.1)
- Theobromine and caffeine LD₅₀ = 100 to 200 mg/kg, however, clinical signs can be seen as low as 20 mg/kg (Table 19.2)

Incidence/Prevalence

- ASPCA Animal Poison Control Center 2006: number 7 hazard encountered by pets
- More common during the holiday season due to increased availability
- Cocoa shell mulch; increasing in popularity for landscaping

Systems Affected

- Gastrointestinal—vomiting and diarrhea
- Urologic—polyuria, polydipsia
- Nervous—hyperactivity, CNS stimulation, seizures
- Musculoskeletal—tremors, hyperreflexia
- Cardiovascular—tachycardia, increased myocardial contractility

| TABLE 19.1 Theobromine Content in Chocolates | | | |
|---|---------------------|----------------------|---------------------|
| Type | Theobromine (mg/oz) | Type | Theobromine (mg/oz) |
| Cocoa Shell Mulch | 400–857 | Semi Sweet Chocolate | 150–257 |
| Cocoa Beans | 314–1228 | Milk Chocolate | 44–63 |
| Cocoa Powder | 150–742 | Hot Chocolate Powder | 11–14 |
| Bakers Chocolate | 390–457 | White Chocolate | 0.26–1.4 |
| Range of theobromine (mg) per ounce (oz) of chocolate | | | |

| TABLE 19.2 Chocolate Toxicity by Weight | | | | | | |
|---|-------------|--------------|--------------|--------------|--------------|--------------|
| Milk Chocolate (44 mg/oz) | | | | | | |
| | 5 kg | 10 kg | 20 kg | 30 kg | 50 kg | 70 kg |
| 1 oz | 9 mg/kg | 4.5 mg/kg | 2.2 mg/kg | 1.5 mg/kg | <1 mg/kg | <1 mg/kg |
| 8 oz (1 C) | 71 mg/kg | 35 mg/kg | 18 mg/kg | 12 mg/kg | 7 mg/kg | 5 mg/kg |
| 16 oz (2 C) | 141 mg/kg | 70 mg/kg | 35 mg/kg | 23 mg/kg | 14 mg/kg | 10 mg/kg |
| 32 oz (4 C) | 282 mg/kg | 141 mg/kg | 71 mg/kg | 47 mg/kg | 28 mg/kg | 20 mg/kg |
| Semi Sweet Chocolate (150 mg/oz) | | | | | | |
| | 5 kg | 10 kg | 20 kg | 30 kg | 50 kg | 70 kg |
| 1 oz | 30 mg/kg | 15 mg/kg | 8 mg/kg | 5 mg/kg | 3 mg/kg | 2 mg/kg |
| 8 oz (1 C) | 240 mg/kg | 120 mg/kg | 60 mg/kg | 40 mg/kg | 24 mg/kg | 17 mg/kg |
| 16 oz (2 C) | 480 mg/kg | 240 mg/kg | 120 mg/kg | 80 mg/kg | 48 mg/kg | 34 mg/kg |
| 32 oz (4 C) | 960 mg/kg | 480 mg/kg | 240 mg/kg | 160 mg/kg | 96 mg/kg | 69 mg/kg |
| Bakers Chocolate (390 mg/oz) | | | | | | |
| | 5 kg | 10 kg | 20 kg | 30 kg | 50 kg | 70 kg |
| 1 oz | 78 mg/kg | 39 mg/kg | 20 mg/kg | 13 mg/kg | 8 mg/kg | 6 mg/kg |
| 8 oz (1 C) | 624 mg/kg | 312 mg/kg | 156 mg/kg | 104 mg/kg | 62 mg/kg | 45 mg/kg |
| 16 oz (2 C) | 1248 mg/kg | 624 mg/kg | 312 mg/kg | 208 mg/kg | 125 mg/kg | 89 mg/kg |
| 32 oz (4 C) | 2496 mg/kg | 1248 mg/kg | 624 mg/kg | 416 mg/kg | 250 mg/kg | 178 mg/kg |
| Chocolate dose based on weight (kg) of the patient and type of chocolate. | | | | | | |
| Shading indicates a dose greater than 100 mg/kg. Ounces (oz), Cup (C). | | | | | | |



SIGNALMENT/HISTORY

- Dogs—puppies and young dogs more commonly; small dogs may be at increased risk
- Cats—rarely

Historical Findings

- Recent chocolate ingestion reported
- Gastrointestinal signs; vomiting and diarrhea (2–4 hours)
- Polyuria/polydipsia
- Hyperactivity and anxiety
- Neurologic signs—tremors, seizures



CLINICAL FEATURES

- Tachycardia
- Tachypnea
- Hypertension
- Hyperthermia
- Tachyarrhythmias
- Hyperreflexia
- Muscle tremors
- Ataxia
- Seizures
- Coma/death



DIFFERENTIAL DIAGNOSIS

- Other toxins: mycotoxins, strychnine, nicotine, pesticides, organophosphates
- Drugs: LSD, amphetamines, digitalis
- Seizure disorder
- Electrolyte/metabolic abnormality; hypomagnesemia and hypocalcemia



DIAGNOSTICS

- CBC and serum biochemistry: hypokalemia
- Urine specific gravity: low
- Stomach content analysis: presence of chocolate and methylxanthine
- Plasma, serum, and urine: theobromine levels



THERAPEUTICS

- The objective is to eliminate the methylxanthine toxin by decontamination and support of clinical signs.

- Induce emesis if alert
- Orogastric lavage
- Activated charcoal
- Intravenous fluid diuresis: intravenous crystalloid fluids; high rates as tolerated by the patient
- Urinary catheter; theobromine is reabsorbed in the bladder

Drug(s) of Choice

Emetics

- Apomorphine: Dogs 0.02 to 0.04 mg/kg IV; 0.1 mg/kg SQ; 0.25 mg/kg conjunctival sac; Cats 0.04 mg/kg IV; 0.08 mg/kg IM or SQ
- Hydrogen peroxide: 1 to 5 ml/kg PO
- Xylazine Dogs: 0.2 mg/kg IV; 0.5 to 1 mg/kg IM or SQ; Cats 0.44 mg/kg IM

Toxin Binding

Activated charcoal: 2 to 8 g/kg PO every 6 to 8 hours; NICH UAA Gel 1 to 3 ml/kg PO

Seizures

- Diazepam: Dogs 0.5 to 2 mg/kg IV; Cats 0.5 to 1 mg/kg IV

Ventricular Tachycardia

- Lidocaine: 1 to 2 mg/kg IV bolus over 30 seconds; 25 to 80 µg/kg per min CRI

Muscle Tremors

- Methocarbamol: 44 mg/kg IV; administer half slowly until relaxation and continue to effect

Precautions/Interactions

- Do not induce vomiting if obtunded, having seizures, or otherwise unable to protect airway
- Cats: Lidocaine use caution; apomorphine is controversial; diazepam may induce liver failure
- Avoid corticosteroids and erythromycin; reduced methylxanthine excretion
- Methylxanthines are excreted in milk and cross the placenta

Alternative Drugs

- Refractory ventricular tachycardia or sinus tachycardia: propranolol (may slow renal excretion) 0.02 mg/kg IV slowly; 0.1 to 0.2 mg/kg PO every 8 hours; metoprolol 0.04 to 0.06 mg/kg IV slow
- Refractory seizures: propofol 3 to 6 mg/kg IV; 8 to 12 mg/kg per hour CRI; phenobarbital 6 mg/kg IV



COMMENTS

Client Education

- Eliminating access to chocolate and warn about the hazards

Patient Monitoring

- Intravenous fluid ins and urinary catheter outs should be calculated in most severe cases.
- Seizure watch
- Heart rate, ECG, and blood pressure every 1 to 4 hours, unless continuous monitoring is warranted
- Temperature every 4 hours for hyperthermia
- Renal function

Possible Complications

- Pregnant animals; risk of teratogenesis
- Nursing animals; risk of neonate stimulation

Expected Course and Prognosis

- May take up to 10 hours for full absorption
- Expected course: 12 to 48 hours of treatment ($t_{1/2} = 17.5$ hrs)
- Prognosis: Complete recovery with treatment; if treatment is started within 2 to 4 hours of ingestion. Guarded with advanced neurologic and cardiovascular signs

Abbreviations

- cAMP: cyclic adenosine monophosphate
- CBC: complete blood count
- CNS: central nervous system
- CRI: constant rate infusion
- IV: intravenously
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Campbell, A, and Chapman, M. *Handbook of Poisoning in Dogs and Cats*, pp.106–110. Malden: Blackwell Sciences Ltd, 2000.

Stidworthy, MF, Bleakley, JS, Cheeseman, MT, and Kelly, DF. Chocolate poisoning in dogs. *Vet Rec* 1997;141:28.

Author: Stacy D. Meola

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Gary D. Osweiler

Chylothorax



DEFINITION/OVERVIEW

- The accumulation of chyle in the pleural space
- Chyle—fluid that is absorbed by lacteals from the intestines. It is composed of mainly lymph and triglycerides.
- Thoracic lymphangiectasia—dilated lymphatics. Occurs in many animals with chylothorax.
- Fibrosing pleuritis—condition that can be caused by chronic irritation of the pleurae from chyle. It results in inflammation and thickening of the pleurae, which causes decreased ventilatory capacity.



ETIOLOGY/PATHOPHYSIOLOGY

- Chyle flows from lymphatics in the mesentery to the cisterna chyli in the abdomen, which then continues in the thorax as the thoracic duct. The thoracic duct empties into the venous system.
- In most cases of chylothorax, abnormal flow or pressures in the thoracic duct are thought to result in the exudation of chyle from dilated thoracic lymphatic vessels into the pleural space.
- Lymphangiectasia is believed to result from either increased lymphatic flow (due to increased lymph formation), decreased lymphatic drainage (due to high venous pressures), or the simultaneous occurrence of both processes.
- May be caused by any disease that increases systemic venous pressures (right-sided heart failure, mediastinal neoplasia, cranial vena cava thrombi, or fungal granulomas).
- Thoracic duct rupture due to trauma is an uncommon cause of chylothorax in dogs and cats.

Incidence/Prevalence

- Unknown

Geographic Distribution

- Worldwide

Species

- Dogs and cats

Breed Predilection

- Dogs—Afghan hounds and Shiba Inus
- Cats—Asian breeds (e.g., Siamese and Himalayan)

Mean Age and Range

- Any age can be affected.
- Cats—may be more common in older cats (possibly associated with neoplasia)
- Afghan hounds—middle-aged
- Shiba Inus—young (less than 1–2 years old)

Systems Affected

- Respiratory—chylous effusion or fibrosing pleuritis interferes with lung expansion.
- Cardiovascular—decreased intravascular fluid volume due to third spacing of fluid.
- Acid-base, electrolytes—can contribute to electrolyte derangements that include hyponatremia and hyperkalemia due to third-spacing of fluid.



SIGNALMENT/HISTORY

Historical Findings

- Most common presenting signs are respiratory difficulty or cough.
- Sometimes duration of cough is months prior to examination.
- Tachypnea
- Depression
- Anorexia
- Weight loss
- Exercise intolerance

Physical Examination Findings

- Muffled heart and lung sounds
- Increased bronchovesicular sounds in dorsal lung fields
- Cyanosis
- Pale mucous membranes
- Decreased anterior thoracic compressibility in cats with cranial mediastinal mass and pleural effusion
- If heart disease is present:
 - Dysrhythmia
 - Murmur
 - Jugular pulses associated with right-sided heart failure

Risk Factors/Causes

- Cranial mediastinal masses (i.e., mediastinal lymphosarcoma, thymoma)
- Heart disease (i.e., cardiomyopathy, pericardial effusion, heartworm infection, tetralogy of Fallot, tricuspid dysplasia, cor triatriatum dexter)
- Trauma
- Fungal granuloma
- Venous thrombus
- Congenital abnormality of thoracic duct
- Lung lobe torsion
- Diaphragmatic hernia
- Idiopathic (most common cause)



DIFFERENTIAL DIAGNOSIS

Differentiating Causes

- Any cause of respiratory distress or coughing
- Differential diagnoses for exudative pleural effusion include pyothorax, effusion from FIP, neoplastic effusion, pseudochylous effusion, and chylous effusion.
- Pseudochylous effusion is effusion that has a milky appearance due to a high cellularity, but has a low triglyceride level and a high cholesterol level compared to serum.



DIAGNOSTICS

Complete Blood Count/Chemistry/Urinalysis

- Often normal
- May find lymphopenia and hypoalbuminemia

Other Laboratory Tests

Pleural Fluid Analysis

- Characteristics—milky and opaque, usually white in color but can range from yellow to pink; may not appear milky in animals with long-term inappetence/anorexia (Figure 20.1)
- Protein content—inaccurate measurement on refractometer due to high lipid content
 - Total nucleated count—usually less than 10,000 cells/ μ l

Fluid Cytology

- Mostly small lymphocytes or neutrophils
- Nondegenerative neutrophils may be predominate cell type with chronic chylothorax due to prolonged loss of lymphocytes or when multiple thoracocenteses result in inflammation.
- If abnormal lymphocytes are present, there may be underlying neoplasia.



■ **Figure 20.1** Thoracocentesis and chylous effusion in a cat with restrictive cardiomyopathy.

Additional Tests

- Fluid triglyceride concentration of chylous effusion is higher than serum triglyceride level.
- Fluid cholesterol level is lower than or equal to serum cholesterol level.
- Sudan III stain for lipid droplets
- Ether clearance test of fluid
- Occult heartworm test
- Viral serology (FeLV and FIV) in cats

Imaging

Thoracic Radiography (Figure 20.2)

- Repeat thoracic radiographs after thoracocentesis is performed to remove most of pleural fluid.
- If atelectatic or consolidated lung lobes are noted after pleural fluid is removed, underlying pulmonary parenchymal disease (e.g., lung lobe torsion, pneumonia, neoplasia) or pleural disease (e.g., fibrosing pleuritis) should be suspected.

Ultrasonography

- Should be performed before removing fluid if possible as fluid can enhance visualization of thoracic structures
- Used to detect underlying cardiac disease, pericardial disease, and mediastinal masses



■ **Figure 20.2** Ventrodorsal thoracic radiograph of a cat with chylous pleural effusion and a cranial mediastinal mass. Note the widening of the mediastinum cranial to the cardiac silhouette.

Diagnostic Procedures

- Thoracocentesis allows characterization of fluid.



THERAPEUTICS

Drug(s) of Choice

- Rutin: 50 to 100 mg/kg PO every 8 hours.
 - One study shows complete resolution of chylous effusion within 2 months of therapy in at least 25 percent of patients. Since chylothorax resolves spontaneously in some animals, more studies need to be performed to see what percentage of chylothorax cases would have resolved without any treatment.

Contraindications

- Severe fibrosing pleuritis is associated with a grave prognosis; medical or surgical treatment is unlikely to be beneficial. This occurs more commonly in cats than in dogs.

Medical Management

- Immediate thoracocentesis for patients with respiratory difficulty and suspected pleural effusion

- Treat underlying cause if possible.
- Medical management with intermittent thoracocentesis when respiratory difficulty is noted
- Perform thoracocentesis under aseptic conditions to reduce risk of iatrogenic infection.
- Chest tubes only in patients with chylothorax due to trauma (rare), patients with rapid fluid accumulation, or postoperative patients
- Rutin
- Low fat diet; may decrease fat content in pleural effusion, which may improve fluid reabsorption from thoracic cavity and decrease chyle accumulation
- Some cases of chylothorax may resolve spontaneously in several weeks or months.
- Most cases of chylothorax due to traumatic rupture of the thoracic duct resolve without surgery within a few weeks.

Surgical Management

- Recommended in patients who do not respond to medical management after 2 to 3 months
- Thoracic duct ligation
 - The theory is that after the thoracic duct is ligated, abdominal lymphaticovenous anastomoses form for the transport of chyle to the venous system, bypassing the thoracic duct.
 - Thoracic duct has multiple branches in the caudal thorax; all of these branches need to be occluded. A mesenteric lymphatic should be catheterized for lymphangiography—facilitates visualization and complete occlusion of all branches of thoracic duct.
 - Success rate reported to be approximately 50 percent in dogs
 - High incidence of continued or recurrent chylous or nonchylous effusion post-operatively
- Thoracic duct ligation and pericardectomy
 - Thoracic duct ligation alone may fail due to thickening of pericardium from chronic irritation by chyle resulting in increased right-sided venous pressures, which would impede the drainage of chyle through lymphaticovenous communications. A pericardectomy may help reduce the occurrence of this.
 - Success rates variable, but reported to be as high as 100 percent
- Thoracic duct ligation and cisterna chyli ablation
 - Thoracic duct ligation alone may lead to caudal thoracic duct and cisterna chyli hypertension, which could be a stimulus for development of collateral lymphatics that causes recurrence of chylothorax after thoracic duct ligation.
 - Cisterna chyli ablation may force disrupted lymphatic channels to form new drainage connections within the abdominal cavity
 - This procedure resulted in resolution of chylous pleural effusion in 88 percent of dogs in one study.
- Thoracic duct ligation, cistern chyli ablation, and pericardectomy
 - Recommended by some surgeons

Other

- If medical management and surgical management fail, there are palliative options to drain the pleural space.
 - Placement of subcutaneous vascular access port connected to an intrathoracic drain allows for chronic chest drainage through a subcutaneous injection port.
 - Historically, other devices and procedures have been tried for palliative treatment of chylothorax, including pleuroperitoneal shunts, pleurovenous shunts, and pleurodesis. These options are no longer commonly practiced.



COMMENTS

Miscellaneous

- Diffuse lymphatic abnormalities (i.e., intestinal lymphangiectasia, hepatic lymphangiectasia, pulmonary lymphangiectasia, and chylous ascites) may be present. These findings may be associated with a worse prognosis.
- Young patients with chylothorax may have a better prognosis than older animals due to increased incidence of neoplasia in older patients.

Patient Monitoring

- Monitor closely for respiratory difficulty—thoracocentesis as needed
- Resolution (spontaneously or postsurgery); periodically re-evaluate for several years to detect recurrence

Possible Complications

- Fibrosing pleuritis—most common serious complication of chronic chylothorax
- Immunosuppression—may develop in patients undergoing repeated and frequent thoracocentesis due to lymphocyte depletion
- Hyponatremia and hyperkalemia in dogs undergoing multiple thoracocentesis

Expected Course and Prognosis

- May resolve spontaneously or after surgery
- Chronic disease may result in severe fibrosing pleuritis and persistent respiratory difficulty.
- Euthanasia frequently performed in patients that do not respond to therapy

Abbreviations

- FeLV: Feline leukemia virus
- FIP: Feline infectious peritonitis
- FIV: Feline immunodeficiency virus

Suggested Reading

- Fossum, TW, Birchard, SJ, and Jacobs, RM. Chylothorax in thirty-four dogs. *J Am Vet Med Assoc* 1986;188:1315–1318.
- Fossum, TW, Evering, WN, Miller, MW, et al. Severe bilateral fibrosing pleuritis associated with chronic chylothorax in dogs and cats. *J Am Vet Med Assoc* 1992;201:317–324.
- Fossum, TW, Mertens, MM, Miller, MW, et al. Thoracic duct ligation and pericardectomy for treatment of idiopathic chylothorax. *J Vet Intern Med* 2004;18:307–310.
- Hayashi, K, Sicard, G, Gellasch, K, et al. Cisterna chyli ablation with thoracic duct ligation for chylothorax: results in eight dogs. *Vet Surg* 2005;34:519–523.
- Thompson, MS, Cohn, LA, and Jordan, RC. Use of rutin for medical management of idiopathic chylothorax in four cats. *J Am Vet Med Assoc* 1999;215:345–8, 339.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Theresa W. Fossum

Coonhound Paralysis



DEFINITION/OVERVIEW

- Acute inflammation of multiple nerve roots and peripheral nerves in dogs, with or without a previous history of contact with a raccoon.
- Proposed animal model for GBS in humans.



ETIOLOGY/PATHOPHYSIOLOGY

- Largely unknown, although coonhound paralysis is closely linked with raccoon contact, specifically with raccoon saliva.
- Suspected immune-mediated disease for both coonhound paralysis and ACIP.
- ACIP has been suspected to be associated with previous vaccination and possibly respiratory or gastrointestinal viral or bacterial infections.
- Most commonly recognized polyneuropathy in dogs in North America, although the incidence is low.
- The distribution of coonhound paralysis is relative to the distribution of raccoons (North and Central America, as well as parts of South America).
- ACIP is found worldwide.

Systems Affected

- Nervous—the peripheral nervous system with the most severe involvement being in the ventral nerve roots and ventral root components of the spinal nerves.
- Cranial nerves are affected in some patients, with the most commonly affected nerves being VII and X.
- Respiratory paralysis may occur in severe cases, secondary to intercostal and phrenic nerve involvement.



SIGNALMENT/HISTORY

- In coonhound paralysis, there is a predilection for coonhounds and other raccoon hunting breeds, but any breed in contact with raccoons is susceptible.

- Previous disease does not confer immunity and may actually increase the risk of disease recurrence.
- Multiple bouts of coonhound paralysis are not uncommon in the same dog.
- There are no breed predilections with ACIP.

Historical Findings

- Neurological signs appear 7 to 14 days after contact with a raccoon or after other antecedent precipitating events (i.e., vaccinations).
- Owners initially note a stiff-stilted gait in all four limbs.
- There is a rapid progression to a flaccid lower motor neuron tetraparesis to tetraplegia.
- Appetite and water consumption usually remain normal, although dogs may not be able to voluntarily reach food or water.
- Urination and defecation also are usually reported as being normal.
- Initial progression of disease usually occurs over 4 to 5 days, although occasionally progression can occur up to 10 days.



CLINICAL FEATURES

Neurologic Examination Findings

- Usually neurological signs are symmetrical.
- There is a generalized hyporeflexia to areflexia, hypotonia to atonia, and severe neurogenic muscle atrophy (more chronic change).
- Pelvic limbs are usually more severely affected than the thoracic limbs.
- Respiration may be labored in severely affected dogs with occasional progression to respiratory paralysis.
- Aphonia or dysphonia is common.
- Facial paresis, if present, will be bilateral with incomplete palpebral closure in many patients.
- Pain sensation is intact, although many dogs initially demonstrate a hyperesthesia because of variable dorsal nerve root inflammatory involvement.
- Motor dysfunction always predominates.
- Tail wag is invariably intact.



DIFFERENTIAL DIAGNOSIS

- Other acute polyneuropathy
- Distal denervating disease
- Botulism
- Tick paralysis

- Fulminant myasthenia gravis
- Generalized (diffuse) or multifocal myelopathy (involving both cervical and lumbosacral intumescences)



DIAGNOSTICS

- Serum immunoglobulin analysis reveals a high serum IgG but not IgM in some patients.
- There is a serum reaction to raccoon saliva on ELISA. Dogs with coonhound paralysis have a strong positive reaction that decreases in intensity over time. Dogs without clinical disease but with recent raccoon contact also have a strong positive reaction. Dogs with ACIP but with no raccoon contact have a negative reaction.

Cerebrospinal Fluid Analysis

- Lumbar CSF analysis will reveal a high protein without an increase in leukocytes at all stages of disease.
- Cerebellomedullary CSF will only reveal a mildly elevated protein in severely affected patients in the acute stages of disease.
- CSF protein elevation is due to albumin leakage across a disrupted blood-brain and blood-nerve barrier.
- Most patients have no intrathecal production of immunoglobulin.

Electrodiagnostics

- Generalized spontaneous activity is seen on EMG, the severity of which depends on the time of examination after disease onset and the severity of neurologic signs.
- There will be markedly low compound muscle action potential amplitudes after motor nerve stimulation.
- Motor nerve root studies (F waves) will reveal an increased minimum latency.
- Motor nerve conduction velocities may be within normal range in mildly to moderately affected dogs, whereas severely affected patients may have mildly low values.
- Sensory nerve function is usually normal.

Pathologic Findings

- Ventral nerve roots and the ventral root components of the spinal nerves develop the most severe lesions, consisting of various degrees of axonal degeneration, paranodal and segmental demyelination, and leukocyte infiltration (predominantly monocytes and macrophages, with scattered groups of lymphocytes and plasma cells).
- Peripheral motor and mixed nerves are similarly affected, although to a lesser degree.
- Dorsal nerve roots are much less severely affected.



THERAPEUTICS

- Patients should be closely monitored in the progressive stage of the disease (especially during the first 4 days) for respiratory problems.
- If severe respiratory compromise develops, intensive care and ventilatory support may be required.
- Intravenous fluid therapy would only be necessary if the patient is dehydrated due to an inability to reach water.
- Excellent nursing care is essential.
- Patients are able to eat and drink if they can reach food and water but often must be hand fed because of difficulty in moving their limbs and raising their head and neck.
- Intensive physiotherapy is important to decrease muscle atrophy.
- Frequent turning and excellent padding are essential to prevent pressure sores.
- Encourage the patient to try to move as much as possible.

Drug(s) of Choice

- None have been proven in dogs to be effective in improving clinical signs or shortening the course of disease.
- Immunoglobulins at 1 g/kg IV daily for 2 consecutive days or 0.4 g/kg IV daily for 4 to 5 consecutive days; given early has been shown to decrease the severity or shorten recovery time of GBS in humans.
- Immunoglobulin therapy is very expensive, although it could be equally as valuable in dogs.
- Corticosteroids are contraindicated. They do not improve clinical signs or shorten the course of disease. They have been shown to reduce survival in humans with GBS.



COMMENTS

Client Education

- Inform the client that good nursing care is essential.
- Discuss the importance of preventing pressure sores and urine scalding and of limiting the degree of muscle atrophy by diligent physiotherapy (e.g., passive limb movement, massage, electrical stimulation, and swimming as the patient's strength begins to improve).
- Inform the client that the patient needs soft, resilient bedding (straw or fleeces are excellent) that must be kept clean and free of urine and feces.
- Frequent turning (every 3–4 hours), frequent bathing, and adequate nutrition also are important.

Patient Monitoring

- It is important to keep in close contact with the client regarding complications or changes in the patient's condition.
- Perform urinalyses periodically to check for cystitis in tetraplegic or severely tetraparetic patients.
- Ideally, reevaluate the patient at least every 2 to 3 weeks initially.

Prevention/Avoidance

- In dogs with coonhound paralysis, the best prevention for future episodes is to avoid further contact with raccoons. This is often not feasible because of the dog's environment and primary use as raccoon hunters.
- Because raccoons are very common in suburban areas across the country, avoiding contact between household dogs and raccoons also can be challenging.
- Avoid future vaccination if ACIP was definitively linked to a specific vaccine.

Possible Complications

- Respiratory paralysis in the progressive stage of the disease.
- Pressure sores, urine scalding, and cystitis are common in chronically recumbent dogs.

Expected Course and Prognosis

- Most affected dogs recover fully.
- Mild residual neurologic deficits may remain.
- The disease duration is usually several weeks (6–8) in mildly to moderately affected dogs.
- Severely affected dogs can show signs for 3 to 4 months.
- The order of improvement in signs usually follows the order of initial dysfunction.

Abbreviations

- ACIP: acute canine idiopathic polyradiculoneuritis
- CSF: cerebrospinal fluid
- ELISA: enzyme-linked immunosorbent assay
- EMG: electromyography
- GBS: Guillain-Barre syndrome
- IgG: immunoglobulin G
- IgM: immunoglobulin M
- IV: intravenously

Suggested Reading

Cuddon, PA. Electrophysiologic assessment of acute polyradiculoneuropathy in dogs: comparison with Guillain-Barre syndrome in people. *J Vet Intern Med* 1998;12:294–303.

- Cummings, JF, and Hass, DC. Coonhound paralysis: an acute idiopathic polyradiculoneuritis resembling the Landry-Guillain-Barre syndrome. *J Neurol Sci* 1967;4:51–81.
- Cummings, JF, de Lahunta, A, Holmes, DF, and Schultz, RD. Coonhound paralysis: further clinical studies and electron microscopic observations. *Acta Neuropathol* 1982;56:167–178.
- Gehring R, and Eggars, B. Suspected post-vaccinal acute polyradiculoneuritis in a puppy. *J S Afr Vet Assoc* 2001;72(2):96.
- Northington, JW, and Brown, MJ. Acute canine idiopathic polyneuropathy: A Guillain-Barre-like syndrome in dogs. *J Neurol Sci* 1982;56:259–273.

Author: Paul A. Cuddon

Diaphragmatic Hernia



DEFINITION/OVERVIEW

- A DH is disruption of the diaphragm that results in the displacement of abdominal viscera into the thoracic cavity.
- A pleuroperitoneal DH involves displacement of abdominal viscera into the pleural cavity and is typically acquired due to trauma but may rarely be congenital.
- A peritoneopericardial DH is typically congenital and occurs due to failure of the diaphragm to fuse separately from the pericardial sac and results in the displacement of abdominal viscera into the pericardial space.



ETIOLOGY/PATHOPHYSIOLOGY

- Traumatic DHs result from an excessive pressure differential between the abdominal and thoracic cavities.
- When the abdomen is compressed due to trauma (i.e., automobile accident, fall from height), there is increased intra-abdominal pressure that is transmitted across the diaphragm to the thoracic cavity.
- If the glottis is open, the air within the lungs is allowed to escape to allow decreased intrathoracic pressure. The pressure differential allows the diaphragm to tear, creating the hernia.
- With traumatic DH many factors may contribute to respiratory and cardiovascular compromise.
- Loss of diaphragmatic continuity results in loss of negative pressure, which impairs lung expansion.
- Trauma to the chest wall (i.e., rib fractures, flail segment) results in decreased chest wall excursion due to pain and mechanical factors.
- Fluid or air accumulation and organ entrapment within the thorax result in lung compression and hypoventilation.
- Pulmonary contusions may further limit lung expansion and increased capillary permeability due to ongoing inflammation can result in pulmonary edema. Pulmonary contusions result in diffusion impairment and hypoxemia.
- Myocardial contusions may result in cardiac dysrhythmias and decreased cardiac output.

- Hypovolemia due to blood loss may lead to decreased tissue perfusion and multiple organ failure.

Systems Affected

- Cardiovascular—Myocardial contusions may occur due to trauma and cause cardiac dysrhythmias. Dysrhythmias usually develop within 24 to 48 hours of the trauma and will typically resolve within approximately 5 days. Ventricular dysrhythmias are most common; but other dysrhythmias may also occur. Cardiac output may also be decreased due to hypovolemic shock if hemorrhage has occurred.
- Gastrointestinal—The stomach and intestines are commonly displaced into the thoracic cavity with both congenital or traumatic DH; gastrointestinal displacement in the thorax can cause vomiting, inappetence, and weight loss. Gas distension of the stomach and intestines can occur and compromise lung expansion. If the tear or rent in the diaphragm is small, the intestines can become devitalized due to strangulation, volvulus, or entrapment.
- Hepatobiliary—The liver may be displaced into the thorax and its blood circulation or biliary flow can be disrupted.
- Musculoskeletal—Trauma to the chest wall may occur and cause decreased chest wall excursion. Other orthopedic injuries may occur secondary to trauma.
- Respiratory—Respiratory compromise occurs due to loss of negative thoracic pressure, trauma to the chest wall, fluid or air accumulation within the thoracic cavity, pulmonary contusions, and secondary pulmonary edema.



SIGNALMENT/HISTORY

- Congenital—Breed predilection for Weimaraners and cocker spaniel dogs and Himalayan and Persian cats.
 - Congenital DHs may be present at birth but may not become clinically apparent for several years.
- Traumatic—No breed predilection.
 - More common in younger and male animals due to higher potential for roaming.

Risk Factors/Causes

- Free roaming increases risk for trauma.

Historical Findings

- Respiratory distress/orthopnea
- Exercise intolerance
- Tucked up abdomen
- Vomiting
- Difficulty lying down

- Weight loss with chronic DH
- Icterus with liver entrapment
- History of trauma with acquired DH; however some DHs may not be diagnosed for weeks to years if thoracic radiographs were not performed after traumatic event.



CLINICAL FEATURES

- May be an incidental finding on thoracic radiographs
- Respiratory difficulty/orthopnea
- Muffled heart and lung sounds; intestinal sounds or borborygmi may be ausculted within thorax
- Cardiac dysrhythmias may occur secondary to myocardial contusions or shock.
- Signs of hypovolemic shock—pale mucous membranes, weak, thready pulses, cool peripheral extremities, hypothermia, or hypotension
- Abdomen palpably “empty”
- Icterus may be noted with chronic hepatic entrapment.
- Congenital DH may coexist with other congenital defects including umbilical and supraumbilical hernias, sternal malformations, and cardiac defects.



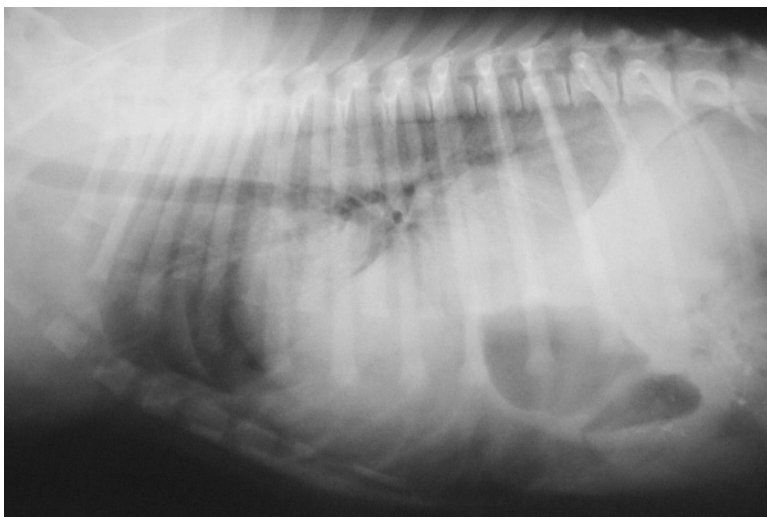
DIFFERENTIAL DIAGNOSIS

- Pulmonary contusions, pleural effusion, acute respiratory distress syndrome, pulmonary thromboembolism, thoracic neoplasia, and lung lobe torsion
- With peritoneal pericardial DH, pericardial effusion, or cardiomegaly due to cardiac disease



DIAGNOSTICS

- Thoracic radiographs—Loss of continuity of diaphragm, soft tissue opacities or gas-filled intestinal loops within thoracic cavity (Figures 22.1 and 22.2). Pleural effusion, pulmonary contusions, and rib fractures may also be seen. Plain radiographs will diagnose approximately 66 percent of hernias.
- If pleural effusion obscures the diaphragm, performing thoracocentesis and then repeating radiographs may be helpful in making a diagnosis.
- With peritoneal pericardial DH, an enlarged cardiac silhouette, dorsal displacement of the trachea, and gas patterns overlying the cardiac silhouette may be seen as well as loss of diaphragmatic continuity.
- Positive contrast peritoneography:
 - Can be performed if plain radiographs not diagnostic.



■ **Figure 22.1** This is a lateral thoracic radiograph of a dog with a traumatic diaphragmatic hernia. The diaphragmatic outline is not visible ventrally. Note the soft tissue opacity within the thoracic cavity and the cranial displacement of the stomach.



■ **Figure 22.2** This is a lateral thoracic radiograph of a cat with a peritoneopericardial diaphragmatic hernia. Note the enlarged cardiac silhouette with dorsal displacement of the trachea. There is loss of continuity of the diaphragm, and there is a soft tissue opacity between the heart and the diaphragm.

- Inject 1.1 ml/kg of water-soluble iodinated contrast solution into the abdomen using aseptic technique. Rotate the patient and elevate the hind quarters then repeat radiographs.
- Contrast material within the thoracic cavity, absence of normal liver lobe outline within the abdomen or incomplete visualization of the abdominal surface of the diaphragm are considered diagnostic for DH.

- Negative contrast peritoneography:
 - Aseptically inject air into the abdomen, then stand the animal on its hind limbs; in this position, take a ventrodorsal radiograph using horizontal beam technique.
 - Air normally accumulates between the liver and the diaphragm; with DH, air will accumulate at the thoracic inlet.
- Upper GI barium study—Can allow visualization of stomach or intestines within the thoracic cavity, but there is potential for aspiration of barium into the lungs and false-negatives can occur if the herniated viscera does not include any portion of the upper GI tract.
- Ultrasonography—Evaluate for continuity of the diaphragm and for abdominal viscera within the thorax.

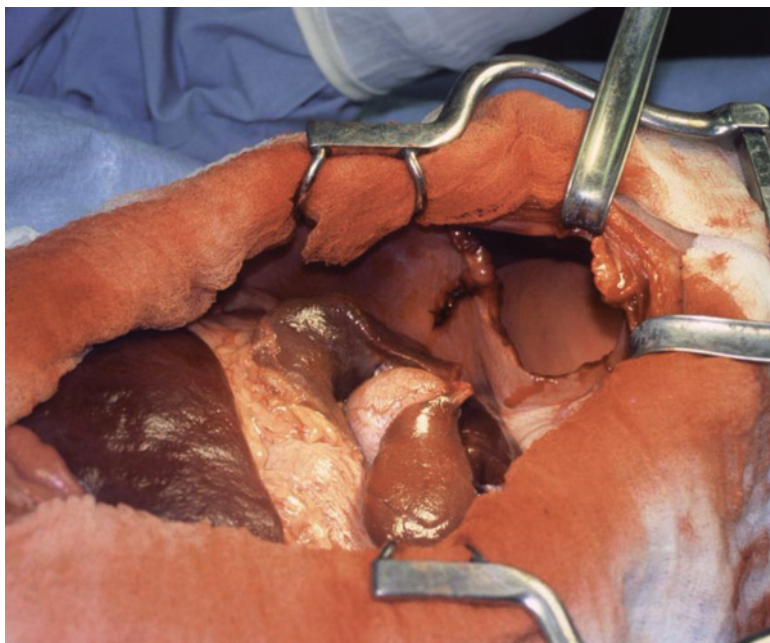
Pathological Findings

- Diaphragmatic rent
- Abdominal viscera displaced into thorax
 - Compromise to blood supply may result in nonviable tissue.
 - Gas distension of the stomach or intestines may be noted.
- Adhesions if DH is chronic
- Thoracic fluid may be noted (i.e., blood, serosanguineous fluid, or chyle).
- Pulmonary contusions or edema and lung atelectasis may be present.



THERAPEUTICS

- Patient stabilization—Administer oxygen, intravenous fluids, analgesia, and antiarrhythmics if indicated. With gas distension of the stomach within the thorax, emergency decompression should be performed by passing an orogastric or nasogastric tube or by percutaneous trocharization or passage of a needle through the chest wall into the stomach.
- Surgical repair of the hernia once the patient is stable—Use a balanced anesthetic protocol that consists of a premedication, induction drug(s), and inhalant or injectable anesthetic drugs. Premedicate patient to reduce anxiety and to decrease the amount of general anesthesia needed. Preoxygenate. Rapid induction (diazepam 0.5 mg/kg IV with propofol 2–4 mg/kg IV, etomidate 1–2 mg/kg IV; or fentanyl 10 µg/kg IV with 0.5 mg/kg diazepam) and intubation. Control positive pressure ventilation once the patient is intubated. Administer perioperative antibiotics. Clip and aseptically scrub both the ventral abdomen and the lateral and ventral thorax in the event that the incision needs to be extended cranially. The surgical approach should be through a ventral midline abdominal incision. Inspect the herniated abdominal contents for viability and gently replace them into the abdomen. If necessary, enlarge the diaphragmatic defect to allow this. Gently break down any adhesions, then resect and remove any devitalized tissue. Close the



■ **Figure 22.3** This is an intraoperative photograph of a diaphragmatic tear. The herniated abdominal viscera has been replaced into the abdominal cavity, and the surgeon is now prepared to repair the rent.

diaphragmatic rent using absorbable or nonabsorbable monofilament suture working from the least accessible portion of the rent toward the surgeon (Figure 22.3). Restore negative intrathoracic pressure by placing a thoracostomy tube or by percutaneous or transdiaphragmatic thoracocentesis. Close the abdomen in a routine manner.

- Postoperatively, supplemental oxygen, intravenous fluid therapy, and analgesia should be administered. If a continued pneumothorax is present, continuous negative suction of thoracostomy tube may be required. Postoperative monitoring should include pulse oximetry or arterial blood gas analysis, electrolytes, glucose, packed cell volume, total protein, ECG, and blood pressure. Urine output should be monitored if there is concurrent urinary tract trauma.

Precautions/Interactions

- Nitrous oxide is contraindicated with anesthesia for DH because it diffuses into the chest cavity, reexpands the gas space within the pleural cavity, and inhibits lung expansion.
- Chamber/mask induction is not recommended due to length of time and depth of anesthesia required before intubation and positive pressure ventilation can be initiated.

Activity

- Limited preoperatively due to respiratory compromise, limited for 2 weeks postoperatively to allow healing

Surgical Considerations

- In the past, delaying surgery for at least 24 hours was recommended to reduce mortality, but recent studies indicate no difference in mortality with early versus delayed surgical intervention. However, the cardiovascular system should ideally be stabilized prior to anesthesia and surgery.
- Animals with gastric herniation, evidence of visceral or vascular compromise, or with severe respiratory compromise associated with herniation of abdominal contents should undergo surgery as soon as possible.
- Congenital DHs should be repaired as soon as possible to avoid adhesion formation and decrease potential for re-expansion pulmonary edema.
- Atelectatic lung should not be rapidly reinflated as this may contribute to re-expansion pulmonary edema.
- Strangulated viscera should be resected without allowing reestablishment of normal circulation to avoid release of oxygen radicals and bacterial toxins into the general circulation.



COMMENTS

Client Education

- Advise owner of cost and prognosis.

Patient Monitoring

- Respiratory rate and quality, SpO₂
- Cardiac rate and rhythm
- Blood pressure
- Pain

Prevention/Avoidance

- Avoid allowing animals to roam free.

Possible Complications

- Pneumothorax
- Reexpansion pulmonary edema
- Reperfusion injury
- Cardiac arrhythmias

Expected course and prognosis

- Mortality rates reported range from 10 to 35 percent.
- Good long term prognosis if patient survives first 24 hours postoperatively

Abbreviations

- DH: diaphragmatic hernia
- ECG: electrocardiogram
- GI: gastrointestinal
- IV: intravenously
- SpO₂: pulse oximeter oxygen saturation

Suggested Readings

- Boudrieau, RJ. Pathophysiology of traumatic diaphragmatic hernia. In: Bojrab, MJ, ed. *Disease Mechanisms in Small Animal Surgery*, 2nd ed., pp. 309–314. Philadelphia: Lippincott Williams & Wilkins, 1993.
- Fossum, TW. Diaphragmatic Hernia. *The Wait Is Over: Diagnosing, Stabilization, and Surgery*. Proceedings IVECC Symposium 2007.
- Gibson, TW, Brisson, BA, and Sears W. Perioperative survival rates after surgery for diaphragmatic hernia in dogs and cats: 92 cases (1990–2002). *J Am Vet Med Assoc* 2005;227(1):105–109.
- Reimer, SB, Kyles, AE, Filipowicz, DE, and Gregory, CR. Long-term outcome of cats treated conservatively or surgically for peritoneopericardial diaphragmatic hernia: 66 cases (1987–2002). *J Am Vet Med Assoc* 2004;224(5):728–732.
- Tillson, DM. Diaphragmatic hernia. In: Harari, J, ed. *Small Animal Surgery Secrets*, pp. 120–123. Philadelphia: Hanley & Belfus, Inc., 2000.

Author: Teresa Dye

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Justin H. Straus

Dilated Cardiomyopathy (DCM)



DEFINITION/OVERVIEW

- Characterized by left- and right-sided dilatation, normal coronary arteries, normal (or minimally diseased) atrioventricular valves, significantly decreased contractile state, and myocardial dysfunction occurring primarily during systole



PATHOPHYSIOLOGY/ETIOLOGY

- Myocardial failure leads to reduced cardiac output and CHF
- AV annulus dilatation and papillary muscle dysfunction promote valvular insufficiency.

Systems Affected

- Cardiovascular
- Pulmonary (edema)
- Urinary (prerenal azotemia)
- All organ systems are affected by reductions in cardiac output.

Genetics

- Genetic cause or inheritable susceptibility strongly suspected in most breeds and recently proven in boxer dogs

Incidence/Prevalence

- Estimated at 0.5 to 1.1 percent but may vary based on the local genetics

Geographic Distribution

- Of minimal importance with the exception of Chagas' cardiomyopathy, which is limited to dogs that live in or travel to Southern United States



SIGNALMENT/HISTORY

Species

Canine

Breed Predilections

- Doberman pinschers, boxer
- “Giant” breeds: Great Dane, Scottish deerhound, Irish wolfhound, cocker spaniels

Mean Age and Range

- Four to 10 years

Predominant Sex

- Males are slightly more predisposed than females in most, but not all, breeds.

Historical Findings

- Respiratory—tachypnea, dyspnea, and coughing
- Weight loss
- Weakness, lethargy, and anorexia
- Abdominal distension
- Syncope
- Some dogs are asymptomatic, but most asymptomatic or preclinical dogs are identified during targeted screening.

Physical Examination Findings

- Weakness, depression, and possibly cardiogenic shock
- Hypokinetic femoral pulse from decreased cardiac output
- Pulse deficits with AF, VPC, PVT
- Jugular pulses from TR, arrhythmias, or right-sided CHF
- Breath sounds may be muffled.
- Pleural effusion
- Pulmonary crackles may be noted if there is pulmonary edema.
- S₃ or summation gallops are common.
- MR and or TR murmurs are frequently noted but usually soft.
- Auscultatory evidence of cardiac arrhythmias is common.
- Slow capillary refill time, possible cyanosis
- Hepatomegaly with or without ascites due to right-sided heart failure

Risk Factors/Causes

- Breed predisposition
- Primary mechanism yet to be identified, although familial aspects are suspected in most
- Proposed—viral, protozoal, immune mediated, or nutritional causes



DIFFERENTIAL DIAGNOSIS

- Endocardiosis
- Congenital heart disease
- Heartworm disease
- Bacterial endocarditis
- Cardiac tumors and pericardial effusion
- Airway obstruction—foreign body, neoplasm, or laryngeal paralysis
- Primary pulmonary disease—bronchial disease, pneumonia, neoplasia, aspiration, or vascular disease (heartworms)
- Pleural effusions—pyothorax, hemothorax, or chylothorax
- Trauma—diaphragmatic hernia, pulmonary hemorrhage, or pneumothorax



DIAGNOSTICS

Laboratory Tests

- Routine hematologic tests and urinalysis are usually normal unless altered by severe reductions in cardiac output (e.g., prerenal azotemia, elevated ALT, low Na^+), aggressive therapy for heart failure (e.g., hypokalemia, hyponatremia, and metabolic alkalosis from diuresis) or concurrent disease.

Electrocardiography

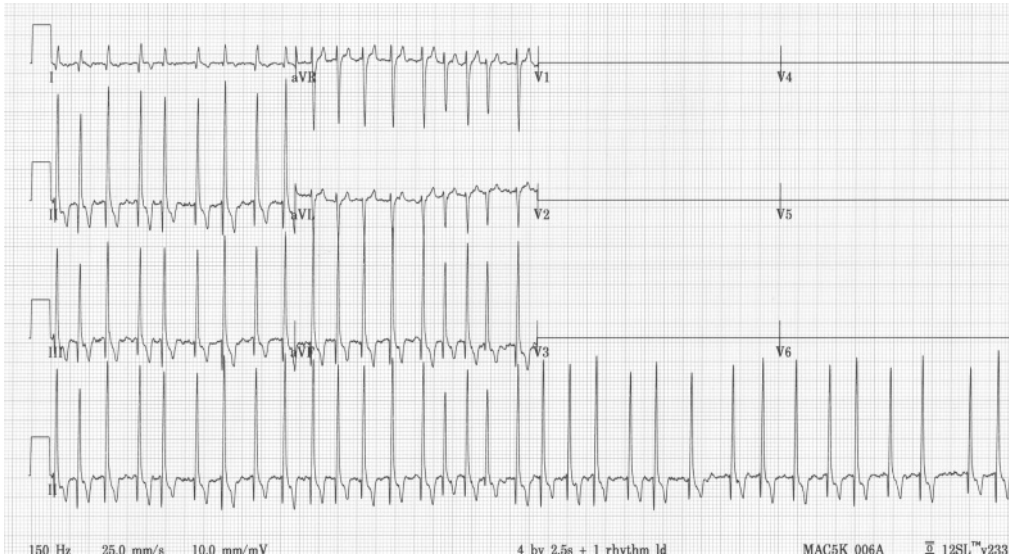
- Sinus rhythm or sinus tachycardia with isolated atrial or ventricular premature complexes
- AF is commonly documented at the time of initial clinical presentation (Figure 23.1).
- Ventricular tachycardia is common in Doberman pinschers and boxers (Figure 23.2).
- Increased QRS (>0.06 sec) duration or increased voltages ($R > 3.0$ mV lead II) suggesting LV dilatation
- Many have “sloppy” R wave descent with ST-T coving, suggesting myocardial disease or LV ischemia.
- Low QRS voltages may be seen with pleural effusion, pericardial effusion, or concurrent hypothyroidism.

Echocardiography

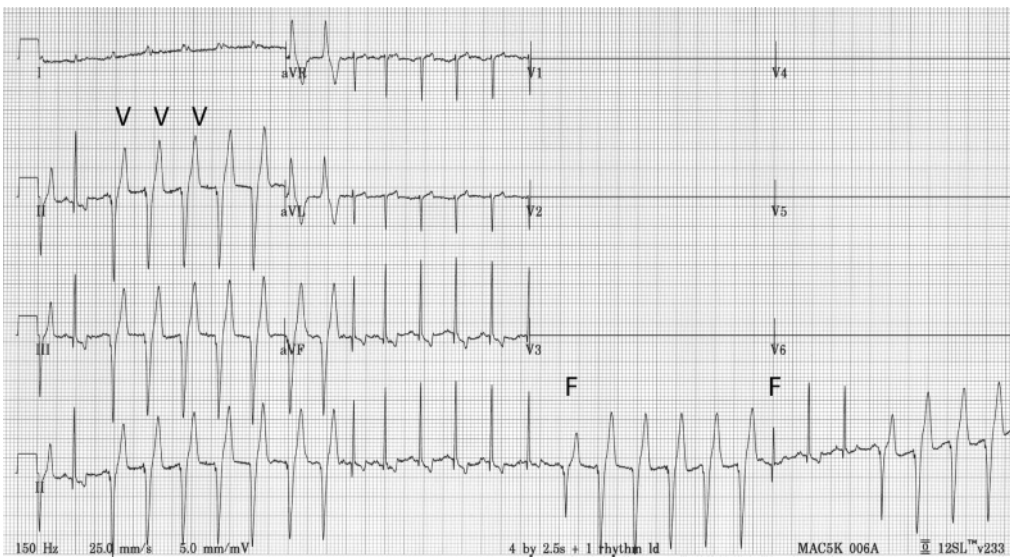
- “Gold standard” for diagnosis
- Ventricular and atrial dilatation
- Myocardial systolic dysfunction documented by low FS% (Figure 23.3)
- Doppler studies may document MR or TR and diastolic dysfunction.

Radiography

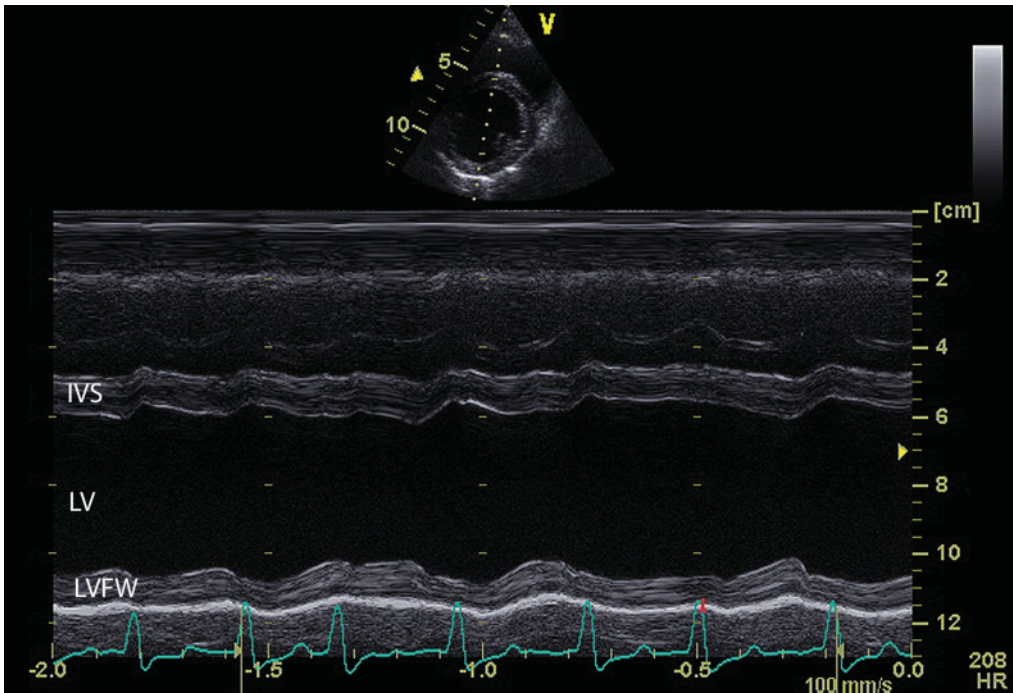
- Generalized cardiomegaly and signs of CHF are common (Figure 23.4).
- LVE and LAE may be most evident in early cases.



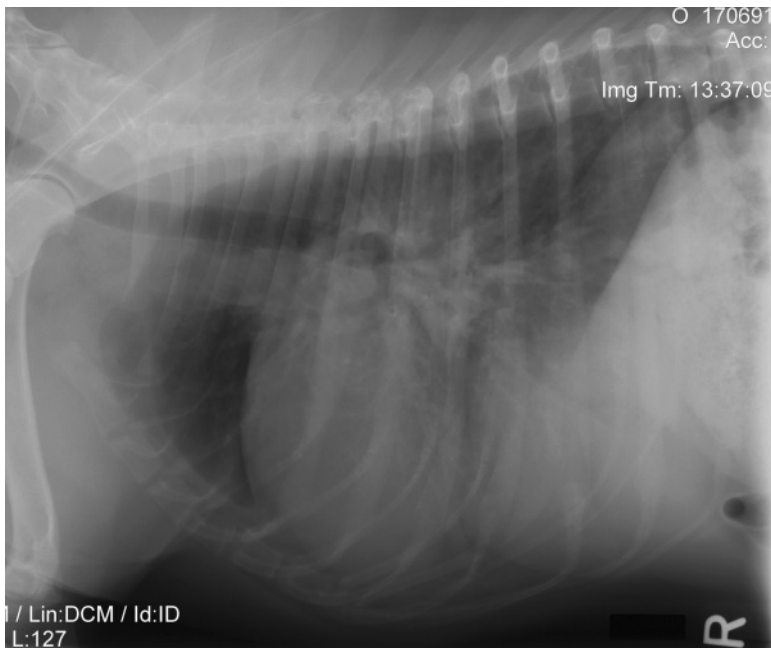
■ **Figure 23.1** Six lead electrocardiogram documenting a rapid irregular cardiac rhythm with no demonstrable P-waves in any lead. These are the diagnostic electrocardiographic features of atrial fibrillation. The R-wave amplitude in lead II frequently exceeds 3 mV suggestive of left ventricular enlargement. (Paper speed = 25 mm/sec; 1 cm = 1 mV.)



■ **Figure 23.2** Six lead electrocardiogram from a dog with dilated cardiomyopathy. The primary cardiac rhythm is sinus with frequent ventricular premature complexes (V), which occur in paroxysms. Fusion beats (F) are seen at the start and termination of the ventricular paroxysm.



■ **Figure 23.3** Left ventricular M-mode echocardiogram from a dog with dilated cardiomyopathy. Notice the dilation of the left ventricle (LV) with the diameter approaching 6 cm in diastole. Additionally the percent change in the left ventricular lumen between diastole and systole (FS%) is markedly reduced.



■ **Figure 23.4** Lateral and ventrodorsal thoracic radiographs from a male Doberman pinscher with congestive heart failure secondary to dilated cardiomyopathy. Notice the modest generalized cardiomegaly with perihilar pulmonary parenchymal infiltrates consistent with a diagnosis of pulmonary edema.

- Doberman pinschers: LAE is often prominent with pulmonary edema often patchy and diffuse
- Pleural effusion, hepatomegaly, ascites

Diagnostic Procedures

- Percutaneous endomyocardial biopsy with histopathology, quantitative myocardial carnitine assay
- Serum taurine levels should be evaluated in atypical breeds.

Gross and Histopathologic Findings

- Dilation and thinning of all chambers
- Slightly thickened endocardium with pale areas within the myocardium (i.e., necrosis, fibrosis)
- Histopathologic (light) changes are minimal: small areas of myocyte atrophy, myocytolysis, myocardial necrosis, and fibrosis



THERAPEUTICS

- With the exception of severely affected dogs, most therapy can be administered on an outpatient basis.

Drug(s) of Choice

- First identify and address most pressing patient problems: CHF (left- or right-sided), arrhythmia, hypothermia, renal failure, or markedly reduced forward cardiac output (shock).

Initial Stabilization

- Treat hypoxemia with oxygen (O₂) administration; prevent heat loss if hypothermic (warm environment).
- Administration of intravenous or subcutaneous fluids (D₅W or 0.45% NaCl with 2.5% dextrose) should be avoided, given only after pulmonary edema is controlled or pleural effusion has been aspirated.
- If there is pulmonary edema: furosemide (1–4 mg/kg IV every 20–40 minutes until respiratory rate is reduced by 25–50 percent then 1–2 mg/kg two to three times a day for the first 2–3 days)
- Pimobendan 0.25 to 0.3 mg/kg PO twice a day has been proven to increase survival and provide rapid (2–6 hours) hemodynamic benefit.
- If there is significant pleural effusion, drain each hemithorax with an 18- to 20-gauge butterfly catheter.

- If there is severe heart failure and cardiogenic shock, pimobendan and dobutamine may both be used. This combination may predispose to clinically important arrhythmias particularly in the hypoxic dog.
- Digoxin—oral therapy
- Dobutamine—5 to 10 µg/kg per minute infused for 24 to 72 hours with care
- If paroxysmal or sustained ventricular tachycardia is present administer lidocaine slowly in 2 mg/kg boluses (up to 8 mg/kg total) to convert to sinus rhythm. Follow with lidocaine infusion (5–100 µg/kg per minute).
- If lidocaine is ineffective administer procainamide slowly in 2 mg/kg intravenous boluses (up to 20 mg/kg total) to convert to sinus rhythm. Follow with a 20 to 50 µg/kg per minute infusion or 8 to 20 mg/kg IM four times a day.

Maintenance Therapy

- Triple therapy (ACE inhibitors, pimobendan, and diuretics) is considered by most to represent the standard of care for DCM.
- Enalapril (0.25–0.5 mg/kg PO twice a day) or Benazepril (0.25–0.5 mg/kg PO every 24 hours) should be initiated within the first few days in the therapeutic regimen.
- Furosemide 0.5 to 2 mg/kg once to three times a day is used to control pulmonary edema, pleural effusion, or ascites.
- The addition of spironolactone to standard triple therapy has been shown to confer independent survival benefit.
- A daily maintenance dose of 0.375 to 0.75 mg of digoxin (divided twice a day) is used by many.
- Do *not* exceed 0.015 mg/kg per day and do *not* exceed 0.375 mg per day in Doberman pinschers.
- Digoxin is used only as adjunctive therapy for AF.

Arrhythmias

- In the case of AF, slowing of the ventricular rate response is achieved with chronic administration of atenolol (0.75–1.5 mg/kg PO twice a day) or diltiazem (Dilacor 3–7 mg/kg PO twice a day) combined sometimes with digitalis.
- The therapeutic goal is obtaining a resting ventricular rate between 100 and 140 beats per minute.
- This therapy merely controls the ventricular rate, by depressing AV nodal conduction; it generally does not convert the rhythm from AF to sinus rhythm.
- Recent studies have suggested that amiodarone may result in conversion of AF to normal sinus rhythm in a small subset of patients.
- Chronic oral therapy for VT includes sotalol 1–2 mg/kg PO every 12 hours or mexiletine (5–8 mg/kg PO three times a day)
- These drugs can be combined with a β-blocker if necessary.
- The role of carnitine and taurine in the therapy of DCM is controversial.

Contraindications

- Digoxin should be avoided in severe uncontrolled PVT.

Precautions/Interactions

- β -blockers and calcium channel blockers are negative inotropes and may adversely affect myocardial function.
- β -blockers should never be given to a patient when signs of congestion are present.
- The combination of diuretics and ACE inhibitors may result in azotemia, especially in patients with severe reductions in forward cardiac output or pre-existent renal dysfunction.
- Renal dysfunction, hypothyroidism, and hypokalemia predispose to digitalis intoxication.

Alternative Drugs

- If ACE inhibitors are not tolerated, other vasodilators, including amlodipine, may be used instead.
- The role of β -blockers for cardioprotection is an active area of research but definitive benefit has not yet been established.
- The role of CoQ-10 and fish-oil supplementation is yet to be defined but may be of benefit.
- Caution must be used when homeopathic supplements are given because they commonly contain components with diuretic or digitalis-like properties.

Diet

- Ideally reduce dietary Na^+ below 12 to 15 mg/kg per day but do not manipulate diet until signs of CHF and reduced cardiac output are addressed.
- Severe Na^+ restriction is not necessary when using hemodynamically potent drugs.
- Best to use commercially prepared diets

Activity

- Allow the dog to choose its own level of activity.

Surgical Considerations

- Dynamic cardiomyoplasty, ventricular reduction surgery, and external support devices have been discussed; information regarding surgical success and long-term follow-up is as yet unavailable.



COMMENTS

Client Education

- Emphasize potential signs associated with progression of disease (i.e., decreased activity, collapse, and increased respiratory rate and effort) and adverse side effects of medications (i.e., weakness, anorexia, and lethargy).

Patient Monitoring

- Serial clinical examinations, thoracic radiographs, blood pressure measurements, routine biochemical screens, and ECG are most helpful.
- Repeat echocardiography is rarely informative.
- Serial evaluation of serum digoxin levels (therapeutic range of 0.6–1.0 ng/ml) and serum biochemistries may help prevent iatrogenic problems.

Possible Complications

- Sudden death (arrhythmia)
- Iatrogenic problems associated with medical management

Expected Course and Prognosis

- Always fatal
- Six to 24 months following diagnosis
- Dobermans typically have a worse prognosis (<6 month median survival).
- AF, PVT, and markedly decreased FS% are probably markers for short survival and sudden death.

Age-Related Factors

- Prevalence increases with age.

Synonyms

- Congestive cardiomyopathy
- Giant breed cardiomyopathy

Abbreviations

- ACE: angiotensin-converting enzyme
- AF: atrial fibrillation
- ALT: alanine aminotransferase
- AV: atrioventricular
- CHF: congestive heart failure
- DCM: dilated cardiomyopathy
- ECG: electrocardiogram
- FS%: percent fractional shortening
- LV: left ventricular
- IM: intramuscularly
- MR: mitral regurgitation
- Na⁺: sodium
- NaCl: sodium chloride
- PO: by mouth
- PVT: paroxysmal ventricular tachycardia

- TR: tricuspid regurgitation
- VPC: ventricular premature complex
- VT: ventricular tachycardia

See Also

- Atrial fibrillation

Author: Matthew W. Miller

Disorders of Chloride



DEFINITION/OVERVIEW

- Disorders of chloride include hyperchloridemia and hypochloridemia.
- Derangements of chloride can result in acid-base disturbances and alterations in free water balance.



ETIOLOGY/PATHOPHYSIOLOGY

- Chloride ions account for roughly two-thirds of the anions within the extracellular fluid, including plasma.
- Chloride is the major anion that is filtered at the glomerulus and reabsorbed by the renal tubules.
- The chloride ion concentration within cells is much lower than the plasma concentration. The intracellular concentration varies in different types of cells and is dependent on the resting-membrane potential of the cell.
 - For example, the intracellular concentration of chloride in red blood cells is, on average, 60 mEq/L, whereas the intracellular concentration of chloride in muscle cells is only 2 to 4 mEq/L. The higher intracellular concentration of chloride within the red blood cells allows for the effective movement of chloride in and out of the red blood. This ready movement of chloride is the basis for the “chloride shift.”
- Chloride is the most prevalent anion found in gastric fluid as well as small and large intestinal fluid.
- Chloride ions are both reabsorbed and secreted in the gastrointestinal tract. The colon is extremely efficient at chloride reabsorption.
- Chloride is the second most prevalent ion found in the glomerular ultrafiltrate.
- Fifty to 60 percent of the filtered load of chloride is reabsorbed by the proximal tubule of the nephron.
- Chloride reabsorption also occurs in the thick ascending limb of the Loop of Henle. Loop diuretics such as furosemide act in the Loop of Henle by competing for the chloride site of the $\text{Na}^+\text{-K}^+\text{-2Cl}^-$ carrier.
- Metabolic acidosis is classically divided into hyperchloremic and normochloremic disturbances based upon the anion gap and the chloride concentration.
 - The anion gap represents the difference between measured cations (sodium and potassium) and measured anions (chloride and bicarbonate). Physiologically,

electroneutrality must be maintained so the anion gap represents a clinically useful oversimplification.

- Metabolic acidosis is seen when there is an increase in the concentration of “strong” anions. A strong anion is one which dissociates completely at body pH. Examples include chloride, lactate, and the ketoanions.
- When chloride concentration is increased the sum of the measured anions is unchanged, hence a hyperchloremic or normal anion gap acidosis.
- If the strong anion, which is increased, is unmeasured then the chloride concentration remains normal and the bicarbonate concentration decreases. The sum of the measured anions decreases resulting in a high anion gap metabolic acidosis.
- In metabolic acidosis and chronic respiratory acidosis there is an increase in ammonium chloride excretion. It is common to see hypochloremia in chronic respiratory acidosis.
- The roles of hypochloremia and volume depletion in metabolic alkalosis are topics of debate. There is no debate however, that when lost fluid (i.e., vomitus) contains an excess of chloride relative to bicarbonate, a metabolic alkalosis will occur.
- Hyperchloremia is seen with chronic respiratory alkalosis to decrease renal ammonium chloride excretion and increase chloride reabsorption.



SIGNALMENT/HISTORY

- Hypochloremia has been documented in racing greyhounds.



CLINICAL FEATURES

- Clinical signs are related to underlying disease and acid-base abnormalities.



DIFFERENTIAL DIAGNOSIS

Corrected Hypochloremia

- Lipemia (pseudohypochloremia)
- Loss of chloride rich fluid (i.e., vomitus, diarrhea)
- Administration of diuretics (i.e., furosemide, thiazides) or sodium bicarbonate
- Administration of sodium penicillin (extremely high dose)
- Exercise induced (racing greyhounds)
- Chronic respiratory acidosis
- Hyperadrenocorticism
- Gastrointestinal disease that mimics hypoadrenocorticism (hyponatremia and hyperkalemia)

- In cats:
 - Acute tumor lysis syndrome
 - Primary hypoadrenocorticism
 - Anemia
 - Hemorrhagic pleural effusion
 - Diabetic ketoacidosis

Corrected Hyperchloremia

- Lipemia (pseudohyperchloremia)
- Potassium bromide therapy (pseudohyperchloremia)
- Diarrhea
- Total parenteral nutrition
- Chloride salt therapy (i.e., potassium chloride or ammonium chloride)
- Fluid therapy (0.9% NaCl, hypertonic saline)
- Salt poisoning
- Renal failure
- Renal tubular acidosis
- Hypoadrenocorticism
- Diabetes mellitus
- Chronic respiratory alkalosis
- Administration of acetazolamide or spironolactone



DIAGNOSTICS

- Prior to evaluation, chloride concentration can be “corrected” to account for changes in sodium concentration.
- Canine
 - $\text{Cl}^{-}(\text{corrected}) = \text{Cl}^{-} \times 146/\text{Na}^{+}$
- Feline
 - $\text{Cl}^{-}(\text{corrected}) = \text{Cl}^{-} \times 156/\text{Na}^{+}$



THERAPEUTICS

Hypochloremia

- Therapy is directed at correcting the chloride deficit. This is usually achieved by administering 0.9%NaCl.
- When hypokalemia is also present, potassium chloride can be added to the fluid therapy.
- In the rare instance where volume expansion is not required, therapy with potassium chloride or ammonium chloride can be given.

- The use of sodium chloride or potassium chloride requires intact renal function and the use of ammonium chloride requires both renal and hepatic function.

Hyperchloremia

- Therapy is directed at correcting the underlying disease.
- It is important to consider the chloride content of commonly administered fluids as they often have chloride concentrations in excess of normal plasma.
- In severe metabolic acidosis ($\text{pH} < 7.2$), ammonium chloride therapy may be considered.



COMMENTS

Abbreviations

- NaCl: sodium chloride
- pH: acid-base balance

Suggested Reading

Autran de Morais, HS. Chloride ion in small animal practice: the forgotten ion. *J Vet Emerg Crit Care* 1992;2:11–24.

Author: Teresa M. Rieser

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Peter P. Kintzer

Disorders of Phosphorus



DEFINITION/OVERVIEW

- Phosphorus plays an essential role in cellular structure and function.
- Without phosphorus vital cellular metabolic processes cannot occur efficiently.
- Hypophosphatemia and hyperphosphatemia can be seen in conjunction with a variety of diseases and have important consequences for the affected animal.



ETIOLOGY/PATHOPHYSIOLOGY

- Phosphorus exists in organic and inorganic forms within the body.
- Clinical laboratories measure inorganic phosphate.
 - Ten to 20 percent of the inorganic phosphate is protein bound.
 - The remainder exists as a free anion or complexed with sodium, magnesium, or calcium.
- Phosphate is the major intracellular anion.
- Movement into or out of the intracellular compartment can rapidly change the concentration of serum phosphorus.
- The majority of total body phosphorus is found in bone or soft tissue. Less than 1 percent of the total body phosphorus is found within the extracellular fluid compartment.
- Dogs younger than 1 year may have hyperphosphatemia, which is considered normal. The effect of age is less pronounced in cats, but juvenile cats may tend toward higher serum concentrations.
- Carbohydrate meals or infusions will decrease serum phosphorus due to intracellular shifting.
- Protein intake will increase serum phosphorus concentration.

Hypophosphatemia

- Hemic/Lymphatic/Immune
 - Hypophosphatemia increases red blood cell fragility and results in hemolysis.
 - Reduces 2,3-DPG concentrations, thus impairs tissue oxygen delivery.
 - Impairs bacterial killing, phagocytosis, and chemotaxis by leukocytes.

- Thrombocytes have a shorter survival time.
- Clot retraction is impaired and thrombocytopenia may be seen.
- Neuromuscular
 - Rhabdomyolysis
 - Intestinal ileus
 - Generalized muscle weakness
- Cardiovascular
 - Decreased cardiac contractility
- Respiratory
 - Respiratory failure has been seen in humans with acute, severe, hypophosphatemia.
- Nervous
 - Decreased CNS glucose utilization leading to metabolic encephalopathy
- Renal/Urologic
 - Proximal tubule bicarbonate wasting
 - Decreased titratable acidity
 - Decreased renal ammoniogenesis
- Musculoskeletal
 - Bone demineralization

Hyperphosphatemia

- Endocrine/metabolic
 - Decreased serum calcium
- Musculoskeletal
 - Soft tissue mineralization



SIGNALMENT/HISTORY

- Dogs <1 year of age may have hyperphosphatemia that is considered appropriate (up to 10.8mg/dL) for the age.
- Effect of age is less pronounced in cats, but immature cats may tend toward high normal serum phosphorus.

Risk Factors/Causes

Hypophosphatemia

- Carbohydrate load or insulin administration can result in hypophosphatemia.
- Diabetic patients, especially patients with diabetic ketoacidosis, are at risk.
- Malnourished patients receiving total parenteral nutrition.
- Both antacid and magnesium administration have been associated with hypophosphatemia in humans.
- Tachypnea and respiratory alkalosis can cause hypophosphatemia.

Hyperphosphatemia

- Phosphate enema administration
- Vitamin D intoxication
- Parenteral phosphate administration



CLINICAL FEATURES

- Phosphorus derangements most commonly occur as a result of other underlying disease. Clinical features reflect the underlying condition.



DIFFERENTIAL DIAGNOSIS

Hypophosphatemia

- Cellular translocation
 - Carbohydrate load
 - Insulin administration
 - Respiratory alkalosis
 - Total parenteral nutrition
 - Hypothermia
- Increased renal loss
 - Hyperparathyroidism
 - Renal tubular defects (Fanconi syndrome)
 - Proximal acting diuretics (carbonic anhydrase inhibitor)
 - Eclampsia
 - Hyperadrenocorticism
- Decreased intestinal absorption
 - Dietary deficiency
 - Vomiting
 - Malabsorption
 - Phosphate binder administration
 - Vitamin D deficiency

Hyperphosphatemia

- Cellular translocation
 - Tumor cell lysis
 - Trauma/rhabdomyolysis
 - Hemolysis
 - Metabolic acidosis
- Increased intake
 - Phosphate enema administration

- Vitamin D intoxication
- Parenteral phosphate administration
- Decreased excretion
 - Renal failure
 - Uroabdomen
 - Urethral obstruction
 - Hypoparathyroidism
 - Hyperthyroidism
 - Acromegaly
- Physiologic (Young growing animal)
- Laboratory error
 - Lipemia
 - Hyperproteinemia



DIAGNOSTICS

- Serum phosphorus
 - Due to the effects of fasting and other factors, serial phosphorus measurements are recommended.
- Serum phosphorus <2.0 mg/dL is considered severe hypophosphatemia.



THERAPEUTICS

Hypophosphatemia

- Animals that are asymptomatic for hypophosphatemia but at risk for worsening hypophosphatemia may be supplemented with phosphate.
- Animals that are symptomatic due to hypophosphatemia should be treated with parenteral phosphate supplementation.

Drug(s) of Choice

- Potassium phosphate or sodium phosphate
- Give 0.01 to 0.06 mmol/kg per hour IV; recheck serum phosphorus every 6 to 8 hours. (Note: Remember when supplementing with potassium phosphate, that additional potassium is also being administered.)

Hyperphosphatemia

- Intravenous fluid therapy with 0.9% NaCl enhances phosphorus excretion.
- Administration of glucose or insulin will temporarily decrease serum phosphorus. This is rarely indicated.

Drug(s) of Choice

- Aluminum hydroxide 30 to 90 mg/kg per day. Recheck serum phosphorus in 10 to 14 days and adjust dose accordingly.

Diet

- Phosphorus restriction is accomplished via protein restriction.
- Oral phosphate binders may be indicated in chronic renal failure where dietary restriction of phosphorus is insufficient.

**COMMENTS****Abbreviations**

- CNS: central nervous systems
- IV: intravenously
- NaCl: sodium chloride
- 2,3-DPG: 2,3 diphosphoglycerate

Suggested Reading

DiBartola, SP, and Willard, MD. Disorders of phosphorus: hypophosphatemia and hyperphosphatemia. In: DiBartola, SP, ed. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed., pp. 195–209. St. Louis: Saunders Elsevier, 2006.

Forrester, SD, and Moreland, KJ. Hypophosphatemia causes and clinical consequences. *J Vet Intern Med* 1989;3:149–159.

Author: Teresa M. Rieser

Disorder of Sodium



DEFINITION/OVERVIEW

- Disorders of sodium include hypernatremic and hyponatremic states.
- Sodium disorders reflect derangements of water balance. Therefore, it is imperative to understand water balance when approaching sodium disorders.



ETIOLOGY/PATHOPHYSIOLOGY

- Hypernatremia occurs through three different mechanisms.
 - Pure water loss in which either water is lost through the kidneys (diabetes insipidus) or water is not consumed appropriately to meet insensible loss (hypodipsia).
 - Hypotonic fluid loss in which the loss of free water occurs in excess of the loss of solute. This may occur from either renal or extrarenal causes.
 - Impermeant solute gain is a true increase in the solute concentration.

Systems Affected

Hypernatremia

- Cardiovascular—In the loss of hypotonic fluid or pure water deficits, the lost volume can contribute to interstitial dehydration and compromise of the effective circulating volume.
- Nervous—Increases in osmolality result in the osmotic movement of water out the brain cells. Rapid changes can result in cerebral hemorrhage.
- Respiratory—With a true gain of sodium, volume overload and pulmonary edema may be seen.

Hyponatremia

- Hyponatremia is usually associated with hypo-osmolality. The approach to hyponatremia therefore centers around the plasma osmolality.
 - Hyponatremia (normal plasma osmolality)—occurs due to laboratory error (i.e., hyperlipemia or hyperproteinemia).

- Hyponatremia (high plasma osmolality $>310\text{ mOsm/kg}$) occurs with the addition of an impermeant solute to the ECF. If this solute is not sodium, there is a relative decrease in the serum sodium concentration, but the osmolality is increased. An example would be the intravenous infusion of mannitol.
- Hyponatremia (low plasma osmolality $<290\text{ mOsm/kg}$) occurs when the relative concentration of sodium is less than normal compared to the volume of the ECF. This can occur in hypervolemia, normovolemia, or hypovolemia.
- Cardiovascular—As with hypernatremia, some hyponatremic animals have compromise of the effective circulating volume.
- Nervous—Impairment again is related to rapidity of changes in osmolality.
- With chronic hyperosmolality, the brain will produce idiogenic osmoles, which prevent dehydration of the brain and allow the animal to be relatively asymptomatic.



SIGNALMENT/HISTORY

Risk Factors/Causes

- In the case of pure water deficits, animals without access to water are at risk.
- Animals whose primary access to water is salt water (playing on the beach) may be at risk for true salt gain.

Historical Findings

- Historical findings in acute hypernatremia may include failure to provide the animal access to water or the compromise of that water supply.
- In the case of acute hyponatremia, historical findings may include the ingestion of a large volume of water prior to the onset of clinical signs.



CLINICAL FEATURES

- Often the clinical features are nonspecific but may include anorexia, lethargy, vomiting, muscle weakness, behavioral changes, disorientation, ataxia, seizures, coma, and death.
- Clinical signs may also be referable to the underlying cause.



DIFFERENTIAL DIAGNOSIS

Hypernatremia

- Pure water loss
 - Primary hypodipsia
 - Diabetes insipidus (central or nephrogenic)

- High environmental temperature
- Fever
- Inadequate access to water
- Hypotonic fluid loss
 - Gastrointestinal loss (i.e., vomiting/diarrhea)
 - Third space loss
 - Pancreatitis
 - Peritonitis
 - Cutaneous burns
 - Renal loss
 - Osmotic diuresis (i.e., mannitol, hyperglycemia)
 - Diuretic administration (i.e., furosemide)
 - Chronic renal failure
 - Polyuric acute renal failure
 - Postobstructive diuresis
- Impermeant solute gain
 - Salt poisoning (e.g., homemade play dough, salt water ingestion)
 - Hyperaldosteronism
 - Hypertonic fluid administration (i.e., hypertonic saline)

Hyponatremia

- Normal plasma osmolality
 - Hyperlipemia
 - Hyperproteinemia
- High plasma osmolality
 - Hyperglycemia
 - Mannitol administration
- Low plasma osmolality
 - Volume status: hypervolemia
 - Severe liver disease
 - Congestive heart failure
 - Nephrotic syndrome
 - Renal failure
 - Volume status: normovolemia
 - Psychogenic polydipsia
 - SIADH
 - Myxedema coma
 - Hypotonic fluid administration
 - Drugs that stimulate or prolong the renal effects of vasopressin
 - Volume status: hypovolemia
 - Vomiting
 - Diarrhea
 - Third space loss
 - Pancreatitis

- Peritonitis
- Uroabdomen
- Pleural effusion
- Peritoneal effusion
- Cutaneous burns
- Hypoadrenocorticism
- Diuretic administration



DIAGNOSTICS

- Serum sodium
- Calculated plasma osmolality
 - Calc Osmolality: $2\text{Na} + \text{BUN}/2.8 + \text{glucose}/18$
- Measured plasma osmolality
- Urinalysis
- Additional testing is guided by the suspected underlying cause of the sodium disturbance.



THERAPEUTICS

Hypernatremia

- Pure water loss:
 - Therapy is directed at replacing the free water deficit.

$$\text{Water deficit} = \text{Weight (kg)} \times \left(\frac{P_{\text{Na}(\text{present})}}{P_{\text{Na}(\text{previous})}} - 1 \right)$$

- If the sodium prior to water loss is unknown, assume a normal serum sodium.
- This equation provides the total water deficit in liters.
- When replacing a water deficit, intravenous sources of water include 5% dextrose in water or 0.45% NaCl.
- When using 5% dextrose in water the entire volume administered will be free water. Half of the volume of 0.45% NaCl will be free water.
- Correct water deficits *slowly* (0.5 mEq/hr maximum). Overenthusiastic corrections can result in rapid changes in osmolality, myelinolysis and cerebral edema.
- Hypotonic fluid loss
 - Hypernatremia in this situation is complicated by more severe extracellular volume contraction than pure water loss alone.
 - Initial fluid resuscitation should be an isotonic replacement fluid (Normosol-R, 0.9% NaCl) to correct volume deficits.

- Once the animal is volume replete, free water deficits can be corrected using 0.45% NaCl or 5% dextrose in water.
- Gain of impermeant solute (salt poisoning)
 - These animals are often normovolemic to hypervolemic so fluid therapy should be undertaken cautiously.
 - In an animal with normal cardiac and renal function, the administration of 5% dextrose in water will promote diuresis and natriuresis.
 - Animals with cardiac or renal disease may develop pulmonary edema if additional fluids are administered.
 - Diuretics such as furosemide may promote natriuresis and speed the return of the ECF to normal.
- Hyponatremia
 - Acute, symptomatic hyponatremia is treated with isotonic, crystalloid therapy (0.9% NaCl, Normosol-R). Hypertonic solutions (3% NaCl) are not recommended.
 - Chronic hyponatremia is usually asymptomatic due to hypoosmolality and therapy should be directed at correcting the underlying cause.
 - With some of the underlying diseases, therapy may involve restriction of water intake, sodium restriction, or diuretic therapy. It is important to diagnose the underlying disease before advocating water restriction.



COMMENTS

- One key to successful treatment of sodium disturbances is to correct them slowly. Rapid correction of long-standing derangements can be fatal.

Abbreviations

- ECF: extracellular fluid
- NaCl: sodium chloride
- SIADH: syndrome of inappropriate antidiuretic hormone

Suggested Reading

DiBartola, SP. Disorders of sodium and water: Hypernatremia and hyponatremia. In: DiBartola, SP, ed. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed., pp.47–90. St. Louis: Saunders Elsevier, 2006.

Author: Teresa M. Rieser

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Peter P Kintzer

Drowning and Near Drowning



DEFINITION/OVERVIEW

- Drowning—Death from asphyxia within 24 hours of submersion in water.
- Near drowning—Water submersion followed by survival for at least 24 hours.
- Further classification may include very cold water ($\leq 0^{\circ}\text{C}$), cold water ($5\text{--}20^{\circ}\text{C}$), or warm water ($>20^{\circ}\text{C}$) submersion injuries.
- Secondary drowning—Death from complications of a submersion event greater than 24 hours after the injury.
- Immersion syndrome—Sudden death due to cardiac arrest after sudden immersion in cold water.
- Submersion injury—Any of the above events.



ETIOLOGY/PATHOPHYSIOLOGY

- Following submersion, the rise in carbon dioxide levels in the bloodstream stimulates respiration and the animal subsequently aspirates water. In rare cases (approximately 7–10 percent of humans), laryngospasm or hyperventilation prior to submersion prevents aspiration of water (“dry drowning”).
- In experimental dogs, the four phases of drowning include: 1) breath holding and swimming motions, 2) aspiration of water, choking, and struggling, 3) vomiting, and 4) cessation of movement and subsequent death. Similar observations have been made in cats. The mammalian diving reflex may lead to bradycardia, apnea, and vasoconstriction of nonessential capillary beds.
- Typically, large volumes of water are not aspirated (less than 4 mL/kg in human drowning victims), although aspiration of 1 to 3 mL/kg of fluid leads to impaired gas exchange in the lungs. Fluid aspirated into the lungs produces a vagally mediated pulmonary vasoconstriction and hypertension.
- Aspiration of sea water typically leads to more severe hypoxemia than aspiration of an equal volume of fresh water.
- Regardless of the fluid type, the initial cause of hypoxemia after near drowning is due to ventilation-to-perfusion mismatch and shunting of blood through perfused, but not ventilated, alveoli.
- Following fresh water aspiration, the water moves quickly across the alveolar-capillary membrane and into the microcirculation. The animal's pulmonary

surfactant is diluted, leading to alveolar instability and collapse, which prevents normal ventilation of affected alveoli.

- Hypertonic seawater aspiration leads to surfactant washout from the aspirated fluid and diffusion of interstitial water into the alveoli, thus preventing ventilation.
- Up to 75 percent of blood flow may circulate through hypoventilated lung units following either type of near-drowning injury.
- The submersion time, water temperature, and type of water (fresh versus salt versus chemical water) determine the development and severity of organ damage. In some patients, aspiration of vomitus, sand, silt, and sewage may cause bronchial occlusion, bronchospasm, pneumonia, and inflammatory changes to the alveolar-capillary membranes. In addition, postobstructive pulmonary edema may occur in patients with laryngeal spasm.
- Water temperature can significantly affect the outcome of animals following near-drowning. At temperatures below 15°C, there is a rapid loss of body heat, causing a more rapid onset of fatigue. In addition, the ability to swim is impaired and cutaneous receptors lead to hyperventilation and sensation of dyspnea as soon as the animal enters the water.

Systems Affected

- Respiratory
- Nervous
- Cardiovascular
- Gastrointestinal
- Hemic
- Musculoskeletal



SIGNALMENT/HISTORY

- Dogs and cats younger than 4 months of age are at greatest risk.
- Clinical signs may include respiratory distress, cyanosis, coughing, apnea, auscultable thoracic crackles or wheezes, tachycardia or bradycardia, vomiting, obtunded to comatose mental state, or asystole.

Risk Factors/Causes

- Drowning and near drownings frequently occur in areas where swimming pools, lakes, rivers, canals, oceans, or ponds are present, although indoor drownings are also common (i.e., buckets, bathtubs, hot tubs). More drownings may occur in the summer months.
- Inadequate safety precautions or owner negligence are the most common causes of drowning in small animals.
- Animals that are in or near water at the time of a seizure, head trauma, hypoglycemic event, cardiac arrhythmia, or syncopal episode are also at risk for drowning.

Historical Findings

- Animal is often observed thrashing or gasping in water or is found motionless in water.



CLINICAL FEATURES

Dogs and Cats

- Cyanosis, coughing with or without clear to frothy red sputum, apnea, respiratory distress, auscultable thoracic crackles or wheezes, tachycardia or bradycardia, vomiting, obtunded to comatose, with or without hypothermia, or asystole



DIFFERENTIAL DIAGNOSIS

- Hypothermia, neck trauma, and meningitis should be ruled out.
- In the event of drowning secondary to a seizure, neuromuscular disease, head trauma, hypoglycemic event, cardiac arrhythmia, or syncopal episode, appropriate diagnostics should be performed (i.e., lab work, blood pressure monitoring, electrocardiogram, spinal radiographs, cerebrospinal fluid analysis, and brain imaging).
- The history at the time of presentation is often informative.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Inhalation or ingestion of large amounts of fresh water can lead to hemodilution (decrease in hematocrit and total protein), intravascular hemolysis, and a decrease in serum sodium, chloride, and urine specific gravity. Inhalation or ingestion of hypertonic salt water can lead to hemoconcentration (an increase in hematocrit and total protein) as well as an increase in serum sodium, chloride, and urine specific gravity.
- Acute renal dysfunction or failure may occur in patients who have nearly drowned; renal values and urine output should be closely monitored.
- Increased liver enzyme activity has been reported in dogs following fresh water submersion.
- Disseminated intravascular coagulation may develop following a submersion injury and the resultant hypoxia, hypotension, with or without hypothermia. Therefore, coagulation times, platelet counts, and fibrin(ogen) degradation products or D-dimer levels should be monitored. Thromboelastography or antithrombin levels may also be useful.

- Rhabdomyolysis has been reported in people following a submersion injury and will cause an increase in creatine kinase levels.

Other Laboratory Tests

- Arterial blood gas reveals hypoxemia ($\text{PaO}_2 < 80$ mm Hg), hypoventilation ($\text{PaCO}_2 > 50$ mm Hg), hypoglycemia, and acid-base derangements such as a respiratory or metabolic acidosis.

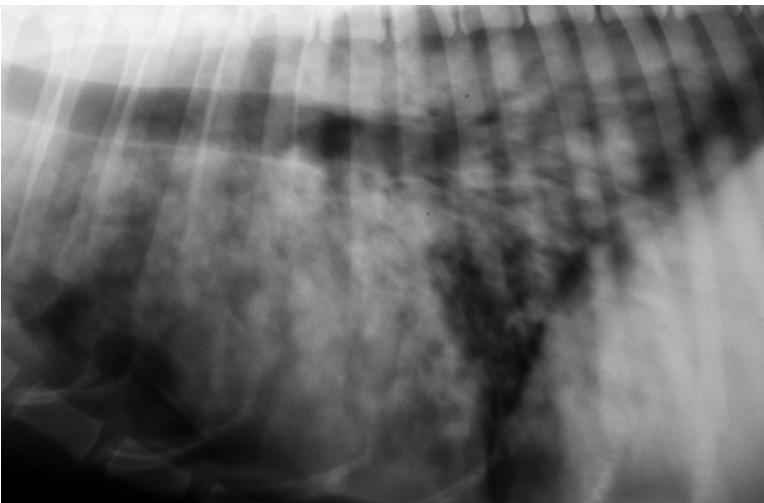
Imaging

Thoracic Radiography

- Radiographic changes may not be detectable for 24 to 48 hours following the near-drowning. A reduction in cardiovascular dimensions may be seen upon presentation if the patient is hypovolemic.
- Focal or diffuse alveolar pattern may be present due to aspiration pneumonia or noncardiogenic pulmonary edema. Mixed bronchial, alveolar, and interstitial patterns may be present, and a radiopaque material filling the airways ("sand bronchogram") has been described (Figure 27.1).
- Foreign body inhalation may produce segmental atelectasis.
- Progression of pulmonary injury to acute respiratory distress syndrome is possible and may appear as bilateral, diffuse, symmetrical alveolar infiltrates.

Diagnostic Procedures

- Endotracheal or transtracheal wash with cytologic evaluation and culture with sensitivities is indicated.



■ **Figure 27.1** A lateral thoracic radiograph of a dog that sustained a submersion injury 6 hours prior. Note the diffuse interstitial and alveolar infiltrates.

- Bronchoscopy may be required for removal of aspirated debris or foreign bodies.
- Electrocardiographic monitoring, continuous pulse oximetry, cervical radiographs or CT, brain MRI or CT, and BAER may be helpful in select cases.

Pathological Findings

- The lungs of animals that have drowned are often heavy, sink in formalin, and contain fluid with or without debris that was aspirated within the airways.
- The stomach may also contain ingested water and debris.
- Rhabdomyolysis may be present in some patients.
- Animals that survive for more than 24 to 48 hours may have evidence of pneumonia, acute lung injury/vasculitis, or end organ damage (i.e., kidneys) secondary to hypoxemia.
- Cerebral edema may be present grossly and histopathologically in some animals.



THERAPEUTICS

- Mouth-to-muzzle resuscitation should be initiated on site. Airway clearance, if obstructed, is the first priority. Cardiopulmonary resuscitation may be necessary.
- Near-drowning victims require emergent, inpatient care.
- Oxygen supplementation should be provided.
- Intubation and mechanical ventilation with PEEP may be required in animals with severe hypoxemia, hypercapnia, or imminent respiratory fatigue.
- Gravitational drainage or abdominal thrusts (the Heimlich maneuver) are not recommended in the absence of airway obstruction due to the high risk of regurgitation and subsequent aspiration of gastric contents.
- Fluid therapy and acid-base/electrolyte management are crucial.
- Gradual rewarming (over 2–3 hours) in hypothermic animals should be performed.
- Prolonged parenteral nutrition may be required in animals with severe neurologic or pulmonary injury.

Drug(s) of Choice

- Mannitol therapy, 0.5 gm/kg of 25% solution IV over 20 minutes, may be beneficial in animals with suspected cerebral edema and elevated intracranial pressures.
- Broad-spectrum antibiotics (i.e., ampicillin 22 mg/kg IV every 8 hours and enrofloxacin 10 mg/kg IV every 24 hours in dogs and enrofloxacin 5 mg/kg every 24 hours in cats) may be necessary if aspiration pneumonia develops, but prophylactic therapy is not recommended and may predispose to the development of antibiotic resistant pathogens.

Precautions/Interactions

- Corticosteroid therapy is not indicated in near-drowning victims and use of this drug could be detrimental in animals with aspiration pneumonia.

Diet

- Parenteral nutrition might be necessary for patients that require prolonged anesthesia for positive pressure ventilation.

Surgical Considerations

- Patients that develop pulmonary abscessation might require a thoracotomy for the removal of affected lung lobes.



COMMENTS

Patient Monitoring

- Frequent or continuous monitoring of heart rate and rhythm, respiratory rate, mucous membrane color and capillary refill time, urine output, arterial blood pressure, rectal temperature, and neurologic status, with or without central venous pressure should be performed.
- Arterial blood gas, complete blood count, biochemical profile, coagulogram, and acid-base status should be rechecked as needed.

Prevention/Avoidance

- Close monitoring of animals (especially young animals or those with seizures or diseases that might cause syncope) near bodies of water, bathtubs, buckets, and so on can help prevent near-drowning accidents.

Possible Complications

Patient

- Aspiration pneumonia, pulmonary abscess(es), pulmonary fibrosis, noncardiogenic pulmonary edema, acute respiratory distress syndrome, gastrointestinal bleeding, diarrhea, vomiting, acute renal failure, permanent neurologic derangements, disseminated intravascular coagulation, or central diabetes insipidus

Owner

- Feelings of guilt and remorse may require counseling.

Expected Course and Prognosis

- The prognosis is directly related to animal's status at time of admission: animals who present severely acidotic ($\text{pH} < 7.0$), require cardiopulmonary resuscitation, or mechanical ventilation have a poor prognosis. Unlike human submersion victims, a retrospective study in dogs found that the level of consciousness at admission was not associated with outcome

- A worse outcome may be associated with increased submersion times.
- Animals who present conscious have a good prognosis if no complications ensue within 2 hours of the event.
- Pulmonary and cerebral edema can occur up to 24 hours after the submersion injury.
- Cold water submersion may be neuroprotective, but long-term neurologic sequelae are possible following all near-drowning injuries. Submersion time may be a more important predictor of survival than rectal temperature.

Synonyms

- Submersion injury

Abbreviations

- BAER: brainstem auditory evoked response
- CT: computed tomography
- IV: intravenously
- MRI: magnetic resonance imaging
- PaO₂: partial pressure of oxygen in blood
- PaCO₂: partial pressure of carbon dioxide in blood
- PEEP: positive end-expiratory pressure

See Also

- Noncardiogenic pulmonary edema

Suggested Reading

- Advanced Challenges in Resuscitation, Part 8, Section 3: Special Challenges in ECC. 3B: Submersion or Near-Drowning, Resuscitation 46(2000) 273–277, Elsevier Science, Ireland Ltd.
- Farrow, CS. Near-drowning (water inhalation). In: Kirk, RW, ed, *Current Veterinary Therapy VIII*, 167–173. Philadelphia: W.B. Saunders, 1983.
- Hawkins EC. Pulmonary parenchymal diseases. In: Ettinger, SJ, and Feldman, EC, eds. *Textbook of Veterinary Internal Medicine: Diseases of the Dog and Cat*, 1086–1087. Philadelphia: WB Saunders, 2000.
- Heffner, GG, Rozanski, EA, Beal, MW, et al. Evaluation of freshwater submersion in small animals: 28 cases (1996–2006). *J Am Vet Med Assoc* 2008;232:244–248.
- Murtaugh, RJ, and Kaplan, PM. *Veterinary Emergency and Critical Care Medicine*, pp. 411–412. St Louis: Mosby Year Book, 1992.

Author: Deborah Silverstein

Dystocia and Uterine Inertia



DEFINITION/OVERVIEW

- Most owners lack medical knowledge regarding the birthing process, and as such, they frequently look to the veterinarian to answer questions and to identify potential problems. The emergency clinician must therefore be familiar with normal reproductive behavior in addition to the common complications that may arise. Dystocia can occur due to either maternal or fetal causes. Uterine inertia is the most common maternal factor while malposition is the most common fetal factor.



ETIOLOGY/PATHOPHYSIOLOGY

- Normal gestation length in the dog may range from 57 to 72 days from the time of first breeding, with an average length of 65 days.
- If the day of ovulation is known, then the whelping date can be accurately predicted because 95 percent of bitches will whelp 63 ± 1 day from the date of ovulation.
- Because cats are induced ovulators, there is generally less variability in gestation length, which ranges from 63 to 65 days. Ovulation may not take place after the first breeding however, so in the event of multiple breedings, uncertainties with regard to gestation length may still be present in the cat.
- As the whelping date approaches, a number of clues may point toward impending parturition. Mammary development, vulvar enlargement, mucoid vaginal discharge, and relaxation of the pelvic ligaments are early signs of approaching parturition. Onset of lactation may be noted in primiparous bitches within 24 hours of parturition, but in multiparous bitches, lactation may occur several days before parturition.
- A sudden drop in body temperature ($<99^{\circ}\text{F}$) is generally noted within 24 hours of parturition in dogs and cats as a result of decreases in progesterone levels, but this finding is not always reliable in cats.
- Normal parturition proceeds in three stages.
 - Stage 1: The first stage is characterized by subclinical uterine contractions and progressive dilation of the cervix. During this stage, which typically lasts for 6 to 24 hours, bitches may show signs of restlessness, apprehension, panting, nesting behaviors, hiding, and anorexia. Queens may be tachypneic, restless, and vocal or

may lie in their nesting boxes, purring. Active expulsion of the fetuses occurs during the second stage of labor.

- Stage 2: The first fetus is usually delivered within 1 hour of onset of stage 2 labor in cats and dogs, with subsequent deliveries every 15 minutes to 4 hours. The entire process generally occurs over 2 to 12 hours, but may take as long as 24 hours with large litter sizes.
- Stage 3: The third stage of labor results in expulsion of the placenta. One placenta should be identified for each fetus delivered. Placentas are usually still attached to the fetus by the umbilical cord and emerge with the fetus, but may emerge within 15 minutes to several hours if they become detached. Lochia, a greenish vaginal discharge, indicates placental separation and may be seen during all stages of labor.
- Following parturition, the discharge gradually becomes red-brown, decreasing in volume over 4 to 6 weeks as uterine involution takes place.

Dystocia

- Dystocia may result from either maternal or fetal factors that prevent delivery from taking place. Uterine inertia is the most common maternal cause of dystocia, seen when the myometrium produces only weak and infrequent contractions that fail to expel a normal fetus through a normal birth canal.
- Primary uterine inertia is diagnosed when gestation has exceeded its expected length with no evidence of progression into active labor. Primary uterine inertia is termed partial if the bitch initiates parturition and expels one or more healthy fetuses, but then subsequently fails to deliver the remaining fetuses as a result of myometrial fatigue.
- Morphologic causes of dystocia are those in which an anatomic abnormality of the bitch or queen results in obstruction of the birth canal (e.g., small birth canal, pelvic fractures).
- Fetal factors that may result in dystocia include malpresentation, oversize, fetal malformations, and fetal death. It should be noted that posterior presentations are considered to be a normal variation in dogs and cats, occurring in approximately 40 percent of deliveries.
- Fetal oversize is a potential cause of dystocia, most commonly seen with single pup pregnancies (Figure 28.1). Fetal death is an infrequent cause of dystocia, increasing the likelihood of malpresentation because of failure to rotate and extend the head and legs, which commonly occurs immediately prior to parturition.
- Fetal malformations are another potential cause of dystocia, with anasarca (generalized subcutaneous edema), hydrocephalus, cerebral and cerebrospinal hernias, abdominal hernias (Figure 28.2), duplications, and rib cage malformations among the more commonly noted.

Systems Affected

- Reproductive
- Endocrine/Metabolic



■ **Figure 28.1** Ventrodorsal radiograph of a bitch with one singlet puppy much too large to be delivered naturally without a c-section.



■ **Figure 28.2** Eviscerated puppy presented on emergency after natural but difficult delivery.



SIGNALMENT/HISTORY

- Primiparous bitches less than 2 years of age are predisposed to dystocia.
- Toy and small brachycephalic breeds, particularly bulldogs, are predisposed to dystocia.
- Signs of dystocia include: active uterine contraction lasting more than 1 hour without passing a fetus, more than 3 to 4 hours without any active uterine contraction, and failure to initiate labor at the end of gestation.

Risk Factors/Causes

- Very large or very small litters predispose to dystocia.

Historical Findings

- Most often the owner observes a change in behavior that may or may not be associated with the passing of a fetus. Most commonly, the owner will note active contractions without passing a fetus, or a period of more than 3 to 4 hours between puppies or kittens.



CLINICAL FEATURES

- On physical examination the queen or bitch may be crying and biting at the vulvar area, have abnormal vaginal discharge (i.e., profuse hemorrhage; odorous mucopurulent discharge; green discharge without production of offspring, indicating placental separation), or signs of systemic illness in the dam—fever, weakness, tremors, etc.
- A vaginal examination should be performed using sterile technique.



DIAGNOSTICS

- Radiographs should be obtained in any animal experiencing dystocia. Radiographs are accurate for assessing the number, size, location, and position of fetuses, as well as maternal pelvic morphology and general status of the abdomen. Fetal viability is more difficult to assess from radiographs, unless evidence of fetal decomposition is present. Signs of decomposition include intrafetal or intrauterine gas patterns, awkward fetal postures, collapse of the spinal column due to loss of muscular support, and overlapping of the bones of the skull.
- Ultrasound may be a more useful tool for assessment of fetal viability, fetal malformations, and fetal distress. Normal fetal heart rates have been reported at 180 to 245 beats per minute in dogs and up to approximately 265 beats per minute in cats. Deceleration of fetal heart rates to less than 180 beats per minute and the presence

of fetal bowel movements on ultrasound have been shown to correlate with severe fetal distress and may indicate a need for rapid intervention.

- A minimum database should include PCV/TS, serum calcium level, and blood glucose.



THERAPEUTICS

- If a fetus is in the birth canal, an attempt should be made to remove it with copious lubrication and gentle, steady traction in a posterior/ventral direction. Best results are obtained with the dam standing while using combined caudal abdominal palpation to direct the fetus into the birth canal. Obstetrical instruments should be avoided if at all possible.
- Medical management with oxytocin should be considered if there is no evidence of obstruction, and fetal and pelvic size appears normal. Calcium gluconate may be considered if weak, infrequent contractions are noted or when lab work reveals hypocalcemia. Retrospective studies have indicated that many patients who fail to respond to oxytocin alone may respond to a combination of calcium and oxytocin.

Drug(s) of Choice

- Oxytocin doses of 0.5–2 units are effective in increasing the frequency and quality of contraction. The oxytocin dose may be repeated in 30 minutes if expulsion of a fetus has not resulted. If labor proceeds and a fetus is delivered, oxytocin may be repeated every 30 minutes as needed to assist in expulsion of the remaining fetuses. If 2 doses of oxytocin fail to deliver a fetus, subsequent doses are not recommended. Note that prior to administration of oxytocin, clients should be cautioned that uterine rupture is a rare but possible complication.
- The dose for calcium gluconate (10 percent solution) as a uterotonic agent is 11 mg/kg diluted in saline and given subcutaneously, or added to intravenous fluids and given slowly while monitoring an ECG for dysrhythmias.
- If hypocalcemia is documented, a dose of 50 to 150 mg/kg IV should be used.
- Subcutaneous administration has been reported to result in irritation and potential granuloma formation, though this is an infrequent complication.

Surgical Considerations

- Surgical management should be considered for the following conditions:
 - Complete primary uterine inertia
 - Partial primary uterine inertia or secondary uterine inertia where large numbers of feti remain and response to drugs is unsatisfactory
 - Fetal oversize
 - Gross abnormalities of maternal pelvis (fractures, masses)
 - Fetal malformations
 - Malpresentation that is not amenable to manipulation



■ **Figure 28.3** Intraoperative photograph of a uterine torsion. Note that puppies in the nontwisted uterine horn were still alive and viable at the time of c-section.

- Past history of dystocia or c-section
- Fetal putrefaction
- Maternal evidence of systemic illness
- Suspicion of uterine torsion (Figure 28.3), rupture, prolapse, or herniation
- Evidence of fetal distress with poor response to medical intervention

Anesthesia

- An anesthetic protocol for c-section should be selected with the goal of maximizing survival of neonates and dam.
- Attempts should be made to minimize exposure of the fetus to anesthetics by keeping the time from induction to delivery as short as possible.
- Ideally, the dam should be clipped and prepped prior to induction (Figure 28.4), equipment should be out, and the surgeon should be scrubbed and ready.
- Induction agents (i.e., propofol 4–7 mg/kg IV slowly) should be given to effect.
 - Propofol (4–6 mg/kg IV) or mask inductions are most commonly used for c-section at this time and have been associated with reduced neonatal mortality in dogs.
- Regional techniques such as line blocks and epidurals may help to minimize the need for other drugs.
 - A line block can be performed using 2 mg/kg lidocaine infused along the ventral midline.
 - Alternately, epidural lidocaine may be administered in dogs at a dose of 2 to 3 mg/kg, not to exceed a total volume of 6 ml.
 - Anesthetic agents that have been associated with increased neonatal mortality include thiopental, ketamine, xylazine, medetomidine, and methoxyflurane.



■ **Figure 28.4** Preoperative photograph of shaving a bitch prior to anesthetic induction to minimize anesthetic time on the bitch and puppies.



COMMENTS

Client Education

- Owners of pregnant dogs or cats should be educated about the clinical signs of dystocia and given clear instructions concerning when veterinary intervention is required.

Expected Course and Prognosis

- The prognosis for medical management of dystocia is guarded, with success rates of 20 to 40 percent in the veterinary literature. Additionally, stillbirth rates have been shown to rise when dystocia is allowed to continue for greater than 4.5 to 6 hours from the time of onset of second stage labor in the dog. For these reasons, the decision to proceed to c-section should not be delayed if response to medical management is poor or unlikely to result in successful delivery. In recent studies, neonatal survival rates following surgical treatment of dystocia have been reported at 92 percent at birth, with 80 percent still alive at 7 days post c-section.

Abbreviations

- ECG: electrocardiogram
- IV: intravenously
- PCV: packed cell volume
- TS: total solids

Suggested Reading

Davidson, AP. Uterine and fetal monitoring in the bitch. *Vet Clin North Am* 2001;31:305–313.

Gaudet, DA. Retrospective study of 128 cases of canine dystocia. *J Am Anim Hosp Assoc* 1985;21:813–818.

Linde-Forsberg, C, and Eneroth, A. Parturition. In: Simpson, GM, ed. *Manual of Small Animal Reproduction and Neonatology*, pp. 127–142. Cheltenham: British Small Animal Veterinary Association, 1998.

Author: Scott P Shaw

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Louis F Archibald

Electric Cord Injury



DEFINITION/OVERVIEW

- Electric cord injury is an uncommon event that occurs when an animal bites an electric cord.
- Other causes of electrocution are uncommon in dogs and cats but can occur.
- Household electrical currents are alternating (60Hz) and dangerous.
- Injury can be due to thermal injury or due to disruption of normal electrophysiologic activity of excitable tissue.
- Pulmonary edema can be a sequela to electrocution and the pathophysiology is thought to be noncardiogenic and likely neurogenic and centrally mediated leading to pulmonary hypertension.
- Cataract formation has been reported following electrocution.



SIGNALMENT/HISTORY

- Seen in dogs and cats
- More commonly reported in dogs
- More commonly seen in young animals or inquisitive animals. In published report age ranged from 5 weeks to 1.5 years, Veterinary Medical Database suggests 2 to 12 months of age
- No breed or sex predilections
- No genetic basis

Signs

- Burns associated with gingiva, tongue, palate (Figure 29.1)
- Singed hair or whiskers
- Acute respiratory difficulty
- Coughing
- Tachypnea
- Orthopnea
- Increased respiratory effort
- Cyanosis
- Crackles during pulmonary auscultation



■ **Figure 29.1** Burn in commissure of mouth and tongue caused by biting an electric cord.

- Cardiac arrhythmias
- Muscle tremors
- Tonic-clonic activity
- Collapse

Risk Factors/Causes

- Chewing electrical cord
- Young animals
- Primarily dogs but also reported in cats



DIFFERENTIAL DIAGNOSIS

- Primary upper airway disease
- Primary lower airway disease
- Primary pulmonary disease
- Left-sided congestive heart failure—may be due to congenital or acquired heart disease. The presence of cardiac murmur or dysrhythmia may help differentiate, however dysrhythmias may be seen with electric cord injury.
- Vitamin K antagonist, rodenticide intoxication—history, PT, PTT, and PIVKA
- Thoracic trauma—history and thoracic radiographs

- Pleural space disease—muffled lung sounds during auscultation and thoracic radiographs
- Thermal or chemical injuries—history, physical examination, and thoracic radiographs
- Exposure to fire and smoke inhalation—history and physical examination
- Atypical pneumonia—history, physical examination, and thoracic radiographs



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Typically no abnormalities
- Possible abnormalities related to tissue necrosis
- Hyperkalemia
- Myoglobinemia
- Myoglobinuria
- Hemoglobinemia
- Hemoglobinuria
- Hyperlactatemia
- Hyperglycemia

Other Laboratory Tests

- Arterial blood gas analysis may indicate hypoxemia.

Imaging

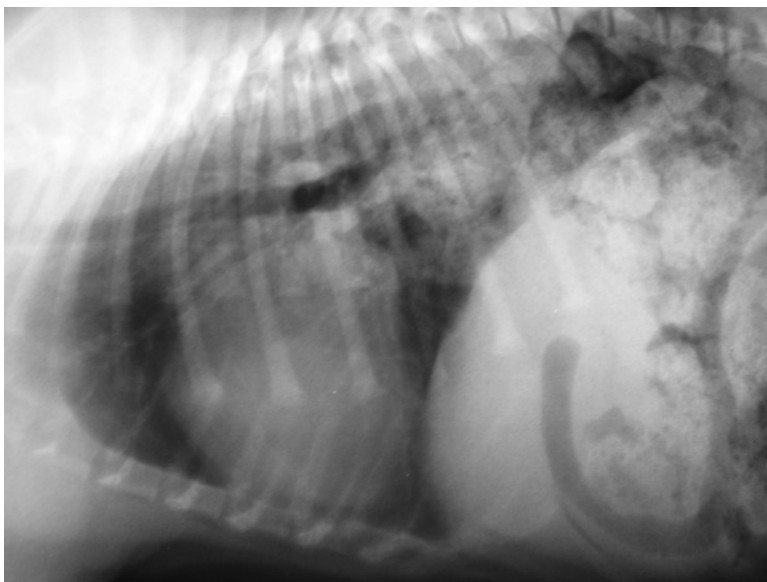
- Thoracic radiographs may help distinguish between cardiogenic and noncardiogenic causes of pulmonary edema.
- The radiographic pattern is usually a generalized, mixed alveolar bronchial pattern. The edema is often most notable in the diaphragmatic lung lobes (Figure 29.2).
- Echocardiography may help identify underlying cardiac disease.

Diagnostic Procedures

- ECG—may help distinguish cardiogenic disease from noncardiogenic disease, however dysrhythmias may be seen with electrocution

Pathologic Findings

- Pink, frothy fluid in airways
- Fluid-filled, congested lungs
- Subendocardial and subepicardial petechiae
- Circumscribed, pale gray or tan oral lesions



■ **Figure 29.2** Lateral thoracic radiograph of a dog with noncardiogenic pulmonary edema secondary to electrocution.



THERAPEUTICS

- If patient is close to live wire, turn off electricity or remove patient to safe area.
- Establish patent airway if patient is unconscious.
- Oxygen supplementation
- Mechanical ventilation may be required.
- Establish venous access.
- Management of thermal injuries

Drug(s) of Choice

- If in shock, treat with intravenous crystalloids (90 ml/kg per hour in dogs, 45–60 ml/kg per hour in cats) or colloids plus or minus hypertonic saline, administer in incremental boluses until blood pressure has normalized.
- If pulmonary edema is present, use furosemide (2–4 mg/kg IV or IM) if hemodynamically stable.
- Corticosteroids have been used but are of unknown value and are not recommended.
- Inotropic support if required
- Antiarrhythmic therapy if required
- Oral and cutaneous burns, treat symptomatically
- Analgesia if required, typically with opioid agents



COMMENTS

Patient Monitoring

- Patient should be monitored until stable.
- Physical examination
- Oral lesions should be monitored and may prevent the animal from eating.
- Electrocardiography
- Central venous pressure
- Blood pressure
- Arterial blood gas analysis
- Thoracic radiographs

Prevention/Avoidance

- Damaged electric cords should be discarded.
- Avoid animal exposure to electric cords.
- Follow child safety rules for a safe home.

Possible Complications

- Infected burn wounds can occur but are uncommon.
- Oral-nasal fistula due to severe burns and tissue necrosis

Expected Course Prognosis

- The prognosis is based on the response to therapy.
- Pulmonary edema can develop as soon as 1 hour and as late as 36 hours after the incident.
- Pulmonary edema associated with electrocution is associated with high mortality (38.5 percent).
- If the patient survives first 24 hours the prognosis improves.
- Resolution of pulmonary edema may take 3 to 5 days.
- Most oral lesions resolve.
- Inappetence related to oral lesions resolves; severe cases may require placement of a feeding tube.

Associated Conditions

- Cataracts have been reported in one dog 18 months after electrocution.

Abbreviations

- ECG: electrocardiogram
- IM: intramuscularly
- IV: intravenously

- PT: prothrombin time
- PTT: partial thrombinblastin time
- PIVKA: protein-induced by vitamin K absence

Suggested Reading

Brightman, AH, Brogdon, JD, Helper, LC, and Everds, N. Electrical cataracts in the canine: A case report. *J Am Anim Hosp Assoc* 1984;20:895–898.

Kolata, RJ, and Burrows, CF. The clinical features of injury by chewing electrical cords in dogs and cats. *J Am Anim Hosp Assoc* 1981;17:219–222.

Mann, FA. Electrical and lightning injuries. In: Silverstein, DC, and Hopper, K. *Small Animal Critical Care Medicine*, pp. 687–690. St. Louis: Saunders/Elsevier, 2009.

Marks, SL. Electrocutation. *Proc North Am Vet Conf* 2004;18:176.

Presley, RH, and Macintire, DK. Electrocutation and electrical cord injury. *Stand Care Emerg Crit Care Med* 2005;7:7.

Author: Steven L. Marks

Epistaxis



DEFINITION/OVERVIEW

- Hemorrhage from the nose (Figure 30.1)



■ **Figure 30.1** Epistaxis secondary to bacterial rhinitis in a Great Dane.



ETIOLOGY/PATHOPHYSIOLOGY

- Results from either local or systemic disease processes
- With local disease, nasal blood vessels rupture after direct trauma or erosion by infection, inflammation, or neoplasia.

- Systemic diseases cause hemorrhage by hemostatic defects (such as thrombocytopenia, vitamin K antagonist rodenticide intoxication) or increased vascular fragility.

Systems Affected

- Respiratory—hemorrhage or sneezing
- Hemic/lymphatic/immune—anemia
- GI—melena or hematemesis

Incidence/Prevalence

- Local processes are the most common cause of epistaxis.

Geographic Distribution

- See other sources for areas endemic to fungal, rickettsial, and other infectious diseases.



SIGNALMENT/HISTORY

- Varies with underlying cause
- Coagulopathies—young, purebred dogs
- Infectious/traumatic—young to middle-aged
- Immune mediated—middle-aged, female dogs
- Neoplasia—older animals

Historical Findings

- Nasal hemorrhage
- Sneezing
- Pawing at nose
- With coagulopathy—hematochezia, melena, hematuria, or hemorrhage in other areas of the body
- With hypertension—blindness, CNS signs

Physical Examination Findings

- Nasal hemorrhage
- Melena—commonly from swallowing blood
- Sneezing
- Pawing at nose
- Facial asymmetry—usually secondary to neoplasia

- Decreased nasal airflow
- Polypoid masses extending from the nares—rhinosporidiosis, phaeohyphomycosis, cryptococcosis, or neoplasia
- Decreased ability to retropulse the globe
- Epiphora or exophthalmos
- Regional lymphadenomegaly
- Oral exam—palatal defect, mass, oronasal fistula, or severe periodontal disease
- Fundic exam—chorioretinitis, retinal hemorrhage, tortuous retinal vessels
- With cryptococcosis—nasal convexity (“Roman nose”)
- With aspergillosis or squamous cell carcinoma—ulceration or depigmentation of the nasal planum
- With coagulopathy—petechia, ecchymosis, hematomas, hematochezia, and hematuria

Risk Factors/Causes

Systemic Disease

Thrombocytopenia

- Spontaneous hemorrhage unlikely unless platelet count is less than 50,000/ μ L
- Decreased production—infectious (i.e., ehrlichiosis, FeLV, FIV, RMSF, hepatosplenitis, septicemia, endotoxemia, or leishmaniasis), toxic (i.e., cytotoxic drugs, estrogens, sulfas, methimazole, or phenobarbital), neoplasia (i.e., myelophthisis or hyperestrogenism), cyclic thrombocytopenia, myelofibrosis, or myelodysplasia
- Destruction—immune mediated (i.e., idiopathic; secondary to drugs, neoplasia, infection, or vaccines) or microangiopathy
- Sequestration in the spleen, liver, or tumors
- Consumption—DIC, vasculitis, or hemorrhage

Thrombocytopathia

- Congenital—vWD, platelet procoagulant activity deficiency in German shepherds or Glanzmann’s thrombasthenia in Great Pyrenees, basset hound, and foxhound thrombopathy
- Acquired—NSAID, hyperglobulinemia (i.e., ehrlichiosis, multiple myeloma, leishmaniasis), or uremia

Coagulation Factor Defects

- More likely to cause intracavitary hemorrhage
- Congenital—hemophilia A (factor VIII deficiency) or hemophilia B (factor IX deficiency)
- Acquired—anticoagulant rodenticide toxicosis, hepatic failure, or DIC

Increased Vascular Fragility

- Hypertension—renal disease, hyperadrenocorticism, hyperthyroidism, pheochromocytoma, or idiopathic
- Hyperviscosity—hyperglobulinemia, polycythemia, or leukemia

- Hyperlipidemia
- Vasculitis—immune mediated or rickettsial

Local Disease

- Trauma
- Oral/Dental disease—oronasal fistula or tooth root abscess
- Foreign body inhalation—grass awns, splinters, or small objects
- Infectious
 - Viral—feline viral rhinotracheitis or calicivirus
 - Bacterial—*Bordetella*, *Pasteurella*, or *Mycoplasma*
 - Fungal—aspergillosis, penicilliosis, cryptococcosis, rhinosporidiosis, phaeohyphomycosis, or pythiosis
 - Parasitic—mites or nematodes
- Immune mediated—lymphoplasmacytic rhinitis or allergic rhinitis
- Neoplasia—adenocarcinoma (most common in dogs), lymphoma (most common in cats), undifferentiated carcinoma, chondrosarcoma, squamous cell carcinoma, fibrosarcoma, hemangiosarcoma, osteosarcoma, melanoma, TVT, plasmacytoma, or nasopharyngeal polyps
- Environmental—humidity changes
- Rupture of arteriovenous malformations
- vWD—Dobermans, Shetland sheepdogs, Airedales, German shepherds, Scottish terriers, and Chesapeake Bay retrievers
- Thrombasthenia—otter hounds and Great Pyrenees
- Thrombopathia—basset hounds and foxhounds
- Hemophilia A—German shepherds
- Hemophilia B—cairn terriers, coonhounds, and Saint Bernard
- Aspergillosis—German shepherds
- Neoplasia—dolicocephalic breeds



DIFFERENTIAL DIAGNOSIS

- In general, systemic causes should be ruled out prior to investigation of nasal disease.
- The signalment, history (including character and duration of nasal discharge/epistaxis), and physical examination can greatly help prioritize differentials.



DIAGNOSTICS

Complete Blood Count/Chemistry/Urinalysis

- Anemia—regenerative or nonregenerative depending on chronicity
- Schistocytes—microangiopathy (neoplasia or DIC)
- Leukocytosis—chronic inflammation or infection

- Leukopenia—chronic ehrlichiosis, cytotoxic drug administration, or sepsis
- Thrombocytopenia
- Macroplatelets—platelet destruction or consumption
- Pancytopenia—bone marrow disease
- Panhypoproteinemia due to blood loss
- Hyperglobulinemia—neoplasia or chronic infections
- High BUN with normal creatinine due to ingested blood or GI hemorrhage
- Azotemia—renal failure—induced hypertension or uremic thrombocytopathia
- Elevated liver enzymes or hyperbilirubinemia—hepatic disease
- Hematuria—coagulopathy
- Isosthenuria—renal failure—induced hypertension or uremic thrombocytopathia
- Proteinuria—hyperglobulinemia

Other Laboratory Tests

- PT/aPTT—abnormal in patients with coagulation factor defects
- BMBT—abnormal in patients with thrombocytopathia, inherently prolonged with thrombocytopenia (not indicated)
- vWF assay
- Thyroid hormone levels in cats
- Serology for heartworm, FeLV, FIV, *Cryptococcus*, *Aspergillus* (poor sensitivity and specificity), *Ehrlichia*, RMSF
- Fecal flotation—ova of nasal parasites may be swallowed and shed in feces
- Serum protein electrophoresis—to distinguish between monoclonal or polyclonal gammopathy

Imaging

- Thoracic radiographs may show evidence of fungal disease or metastatic neoplasia.
- Skull radiographs are difficult to interpret but may reveal osteolysis with neoplasia or fungal rhinitis or opacity in the tympanic bulla in cats with nasopharyngeal polyps.
- Dental radiographs—tooth root abscesses
- CT/MRI—superior to radiography for nasal disease

Diagnostic Procedures

- Blood pressure
- Sedated oral exam
- Cytology of nasal discharge may identify *Cryptococcus* organisms.
- Rhinoscopy—visualization and biopsy of foreign bodies, masses, fungal plaques, and nasal parasites
- Nasal cavity flushing to remove foreign bodies or retrieve tissue for histopathology
- Exploratory rhinotomy/turbinectomy—if less invasive tests are nondiagnostic
- Bone marrow aspirate or biopsy for diagnosis of thrombocytopenia or pancytopenia



THERAPEUTICS

- General—stop hemorrhage and provide supportive care
 - Cage rest, ice packs, pressure to the nose or maxillary arteries
 - Sedation
 - Intranasal vasoconstrictors (i.e., epinephrine or phenylephrine)
 - Packing of the nasal cavity with gauze soaked in Vaseline or dilute epinephrine
 - Ligation of the external carotid artery in refractory cases
 - Intravenous fluids for hypovolemia and blood transfusion for severe anemia
- Specific—varies with cause
 - vWD—fresh frozen plasma or cryoprecipitate
 - Thrombasthenia and thrombopathia—no treatment
 - Hemophilia—plasma or cryoprecipitate for acute bleeding; no long-term treatment
 - Anticoagulant rodenticide toxicosis—plasma followed by vitamin K
 - Immune-mediated thrombocytopenia—immunosuppression
 - Hyperviscosity—plasmapheresis, phlebotomy, treatment of underlying cause
 - Vasculitis—doxycycline for rickettsial disease; corticosteroids for immune-mediated disease
 - Fungal rhinitis—intranasal or oral antifungal therapy or turbinectomy
 - Foreign body—removal by rhinoscopy or rhinotomy
 - Hypertension—ACE-inhibitors, β -blockers, calcium channel blockers, treat underlying disease
 - Neoplasia—varies by tumor type

Drug(s) of Choice

- Immune-mediated thrombocytopenia—prednisone 1 to 2 mg/kg every 12 hours or equivalent doses of other corticosteroids; vincristine 0.02 mg/kg IV once; additional immunosuppression may be needed in refractory cases
- Anticoagulant rodenticide toxicosis—vitamin K 5 mg/kg PO divided daily, 15 to 20 ml/kg fresh frozen plasma
- Fungal rhinitis—itraconazole 5 mg/kg PO every 12 hours for cryptococcosis
- Vasculitis—doxycycline for rickettsial diseases (5 mg/kg every 12 hour for 3–6 weeks), corticosteroids at anti-inflammatory doses
- Hypertension—enalapril or benazepril 0.25 to 0.5 mg/kg every 12 to 24 hours, propranolol 0.5 to 1.0 mg/kg every 8 hour, atenolol 2 mg/kg every 24 hours, diltiazem 0.5 to 1.5 mg/kg every 8 hours (dog), 1.75 to 2.5 mg/kg every 8 hours (cat), or amlodipine 0.625 mg every 24 hours (cat)
- Yunnan Paiyao (Yunnan Baiyao)
 - Dog: open capsule and sprinkle on superficial wounds, bleeding tumors, etc.
 - <15 kg: 1 capsule PO twice a day
 - 15 to 30 kg: 2 capsules PO twice a day
 - >30 kg 2 capsules PO three times a day

- Cat: open capsule and sprinkle on superficial wounds, bleeding tumors, etc.
 - 1/2 capsule PO twice a day

Contraindications

- Avoid drugs that predispose to hemorrhage (i.e., NSAIDs or, heparin) or hypertension (i.e., phenylpropanolamine)

Precautions/Interactions

- Use caution with sedation to avoid hypotension.
- Animals with altered mentation or under sedation may aspirate blood.
- Monitor renal values when using ACE inhibitors.
- Substantial hemorrhage may occur after rhinoscopy or biopsy.



COMMENTS

- Platelet count—in thrombocytopenic animals
- Coagulation profile—in animals with coagulation factor defects
- Blood pressure—in animals with hypertension
- Rhinoscopy to confirm resolution of fungal rhinitis
- Globulins or serum protein electrophoresis—in animals with hyperglobulinemia

Abbreviations

- ACE: angiotensin converting enzyme
- aPTT: activated partial thromboplastin time
- BMBT: buccal mucosal bleeding time
- BUN: blood urea nitrogen
- CNS: central nervous system
- CT: computed tomography
- DIC: disseminated intravascular coagulation
- FeLV: feline leukemia virus
- FIV: feline immunodeficiency virus
- GI: gastrointestinal
- IV: intravenously
- MRI: magnetic resonance imaging
- NSAID: nonsteroidal anti-inflammatory drug
- PO: by mouth
- PT: prothombin time
- RMSF: Rocky Mountain spotted fever
- TVT: transmissible venereal tumor
- vWD: von Willebrand disease
- vWF: von Willebrand factor

Suggested Reading

- Bissett, SA, Drobatz, KJ, McKnight, A, and Degernes, LA. Prevalence, clinical features, and causes of epistaxis in dogs: 176 cases (1996–2001). *J Am Vet Med Assoc* 2007;231(12):1843–1850.
- Gieger, T. Bleeding disorders: Epistaxis and hemoptysis. In: Ettinger, SJ, and Feldman, EC, eds. *Veterinary Internal Medicine*. 6th ed., p. 225–231. Philadelphia: WB Saunders, 2005.
- Mathews, K. Hemorrhage. In: Mathews K, ed. *Veterinary Emergency and Critical Care Manual*, 2nd ed., pp. 619–629. Guelph, Ontario: Lifelearn, 2006.
- Mylonakis, ME, Saridomichelakis, MN, Lazaridis, V, Leontides, LS, Kostoulas, P, and Koutinas, AF. A retrospective study of 61 cases of spontaneous canine epistaxis (1998–2001). *J Sm Anim Pract* 2008;49(4):191–196.

Author: David J. Raczek

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Mitchell A Crystal

Esophageal Foreign Body



DEFINITION/OVERVIEW

- Occurs when a solid object becomes lodged in the esophagus.



ETIOLOGY/PATHOPHYSIOLOGY

- Foreign objects are too large or irregular to pass through the esophagus and become wedged at normal points of narrowing including the thoracic inlet, at the heart base, and distal esophagus.
- Occasionally smaller items (e.g., kibble) become lodged proximal to an esophageal stricture.
- Common esophageal foreign bodies include bones, chew toys, fish hooks, dental chew treats, and hair balls (cats).

Systems Affected

- Gastrointestinal—Esophageal obstruction, esophageal stricture
- Respiratory—Hypoxia, respiratory alkalosis, or pneumonia
- Acid-base



SIGNALMENT/HISTORY

- Small breed dogs are more frequently affected with as many as 84 percent of esophageal foreign bodies occurring in dogs <8 kg when dental chew treats are responsible, and approximately 67 percent when the items are bones or toys.
- No sex, breed, or age predilection; although younger animals more often have dietary indiscretion.

Risk Factors/Causes

- Preexisting esophageal stricture

Historical Findings

- The most common clinical signs include gagging, regurgitation, vomiting, anorexia, ptyalism, lethargy, and cough.
- Ptyalism is observed more frequently in cats.



CLINICAL FEATURES

- Most commonly gagging or dysphagia, regurgitation, anorexia, ptyalism, lethargy, cough, pain and frequent swallowing.
- Ptyalism is observed more frequently in cats.
- Tachypnea can be present due to concurrent pneumonia or pain.



DIFFERENTIAL DIAGNOSIS

- Esophagitis
- Megaesophagus, primary or secondary
- Esophageal stricture
- Vascular ring anomaly
- Esophageal neoplasia



DIAGNOSTICS

Thoracic and Cervical Radiographs

- Often reveal an esophageal foreign body; although it can be poorly defined and appear as a focal soft tissue density (Figure 31.1).
- The opposite lateral view can be helpful when the foreign body is poorly delineated.
- Pneumomediastinum, mediastinal edema, or pleural effusion are suggestive of potential esophageal perforation.

Radiographic Contrast Esophagram

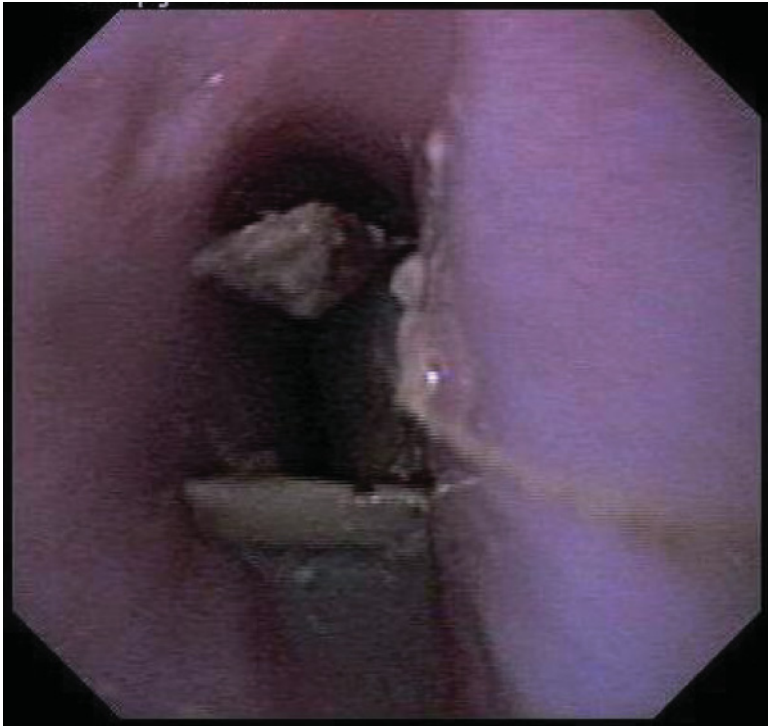
- Some esophageal foreign bodies require radiographic contrast swallow to aid delineation, especially dental chew treats. Avoid barium if there is risk of aspiration.

Esophagoscopy

- Foreign body will be readily visualized (Figure 31.2).



■ **Figure 31.1** Dental chew treat lodged in the mid-esophagus in a dog.



■ **Figure 31.2** Esophagoscopy demonstrating bone foreign body lodged in the esophagus.

Pathological Findings

- Esophageal foreign bodies can lead to significant esophageal inflammation, which leads to a greater risk of stricture or cicatrix formation.
- Pressure necrosis and esophageal perforation can also develop.
- Esophageal perforation will lead to local inflammation and infection (mediastinitis/pleuritis); pneumomediastinum may also be present.



THERAPEUTICS

- The goal of therapy is to remove the foreign body and avoid complications.
- Esophageal foreign bodies are often removed via endoscopic techniques; orad removal is preferred and achieved in approximately 80 percent of cases. Various graspers and forceps are utilized.
- When objects are difficult to grasp, an inflatable object (e.g., Foley urinary catheter) can be passed distal to the object. The balloon is subsequently inflated, and the catheter withdrawn to pull the foreign object orad.
- If the foreign object cannot be removed in an orad direction, then attempts should be made to push it into the stomach. The endoscope itself or other rigid objects (e.g., orogastric tube, long handled forceps, well-lubricated piece of PVC pipe) can be utilized.
- Judicious caution must be employed to avoid damaging a friable esophagus that might lead to esophageal perforation.

Drug(s) of Choice

- Antacids are often utilized following foreign body removal.
 - H₂ antagonists (famotidine, 0.5 mg/kg twice a day)
 - Proton pump inhibitors (omeprazole, 0.7–1.0 mg/kg PO twice a day), and sucralfate (0.5–1.0 g PO three times a day)
- Analgesics are indicated as esophageal injury is often painful.
- Opioids (e.g., tramadol 1–4 mg/kg two to three times a day)
- Avoid NSAIDs for management of pain following esophageal foreign body removal.
- Topical anesthesia can be fashioned with oral lidocaine mixtures.

Diet

- Gastrostomy tubes should be considered when there is severe esophageal inflammation and risk of developing an esophageal stricture.

Activity

- Restrict activity according to recovery from anesthesia or surgery.

Surgical Considerations

- Surgical exploration—thoracotomy—may be required when esophageal foreign bodies cannot be removed or esophageal perforation has occurred.
- Gastrotomy should be performed for esophageal foreign bodies that are advanced into the stomach and are likely to cause gastric or intestinal obstruction. Bone foreign bodies will often dissolve, however can possibly cause an obstruction if they move into the intestinal tract.

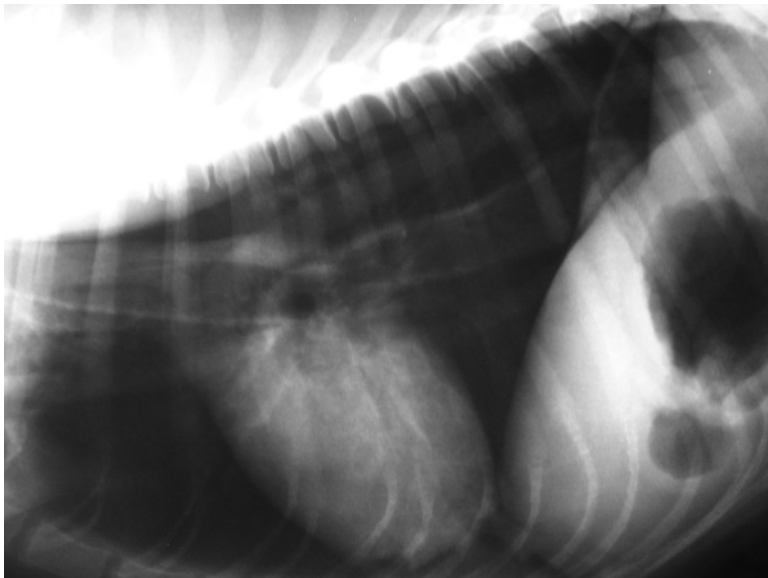


COMMENTS

- Foreign body removal with rigid endoscopes has been reported to be more successful than flexible endoscopes.
- Repeat thoracic radiographs to assess for esophageal perforation (e.g. pneumomediastinum Figure 31.3) following foreign body retrieval should be considered when retrieval was difficult or the esophagus is particularly damaged.
- When there is significant esophageal inflammation, consider repeat endoscopy in 1 to 2 weeks to examine for esophageal stricture formation.

Client Education

- Following esophageal foreign body removal, clients should monitor closely for signs of regurgitation, which may indicate development of an esophageal stricture or cicatrix.



■ **Figure 31.3** Lateral thoracic radiograph of a dog with an esophageal foreign body caudal to the carina. Note the prominent aorta and soft tissues due to air in the mediastinal tissues.

Prevention/Avoidance

- Bones, large chew toys, and dental chew treats should be avoided.

Possible Complications

- Esophageal stricture, approximately 10 to 20 percent of cases; more frequently with dental chew treats
- Esophagitis; more frequently with dental chew treats
- Esophageal perforation and mediastinitis/pleuritis, approximately 12 percent of cases

Expected Course and Prognosis

- Prognosis is fair to good. Overall mortality rates are 7 to 25 percent; esophageal foreign bodies due to dental chew treats tend to have more complications (e.g., perforation or stricture) and a higher mortality rate.

Abbreviations

- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth

Suggested Reading

- Leib, MS, and Sartor, LL. Esophageal foreign body obstruction caused by a dental chew treat in 31 dogs (2000–2006). *J Am Vet Med Assoc* 2008;232:1021–1025.
- Michels, GM, Jones, BD, Guss, BT, et al. Endoscopic and surgical retrieval of fishhooks from the stomach and esophagus in dogs and cats: 75 cases (1977–1993). *J Am Vet Med Assoc* 1995;207:1194–1197.
- Sale, CS, and Williams, JM. Results of transthoracic esophagotomy retrieval of esophageal foreign body obstructions in dogs: 14 cases (2000–2004). *J Am Anim Hosp Assoc* 2006;42:450–456.

Author: Jonathan Bach

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Albert E. Jegens

Feline Bronchitis



DEFINITION/OVERVIEW

- Chronic bronchitis—inflammation in the airways (bronchi and bronchioles); presents clinically as a chronic cough of greater than 2 months' duration.
- Asthma—acute or chronic airway inflammation associated with increased responsiveness of the airways to various stimuli, airway narrowing due to smooth muscle hypertrophy/constriction, reversibility of airway constriction, and presence of eosinophils, lymphocytes, and mast cells within the airways.
- These criteria are often difficult to determine or document, thus FBD is used more commonly to describe the clinical disease in cats of acute or chronic coughing or wheezing accompanied by lower airway inflammation.



ETIOLOGY/PATHOPHYSIOLOGY

- Noxious or allergic stimuli trigger inflammation within the lower airways. The inflammatory mediators cause mucosal airway damage that releases more inflammatory mediators.
- Bronchiolar smooth muscle constriction—reversible either spontaneously or in response to anti-inflammatory drugs.
- Smooth muscle hypertrophy implies chronicity—usually not reversible.
- Increase in mucosal goblet cells, mucus production, and edema of bronchial wall.
- Excessive mucus can cause bronchiolar obstruction and lead to atelectasis or bronchiectasis (dilated airways often obstructed with mucus).
- Chronic inflammation within the airways may lead to fibrosis and lung atelectasis.

Systems Affected

- Respiratory
- Cardiac—chronic airway disease can lead to pulmonary hypertension and secondary right-sided heart disease.

Geographic Distribution

- Worldwide. Parasitic causes of airway inflammation are more common in southern and midwest U.S. states. Heartworm disease is more prevalent in southern U.S. states. *Paragonimus kellicotti* is found in Great Lakes region.



SIGNALMENT

Species

- Cats

Breed Predilections

- Siamese overrepresented

Mean Age and Range

- Any age; more common between 2 and 8 years.

Predominant Sex

- One study shows females overrepresented; however this is not a consistent finding.

Historical Findings

- Coughing (80 percent), sneezing (60 percent), labored breathing or wheezing (40 percent)
- Signs are typically episodic and can be acute or chronic.
- Lethargy and inappetence are occasionally reported.

Physical Examination Findings

- Severely affected cats may present with open-mouth breathing, tachypnea, and cyanosis.
- Increased tracheal sensitivity is common.
- Chest auscultation may reveal crackles or expiratory wheezes or may be normal.
- Labored breathing, typically a moderate to severe increase in expiratory effort with an abdominal push on expiration. Inspiratory effort is usually much less affected.
- Heart rate is typically normal to bradycardic, although stress may result in tachycardia.

Risk Factors/Causes

- Exposure to cigarette smoke, dusty cat litter, hair sprays, and air fresheners could possibly exacerbate disease in some cats.

- Parasitic lung infections are more common in outdoor cats in certain geographic locations.
- Use of potassium bromide has been implicated as a cause for signs of bronchitis or asthma in some cats.
- Triggers of airway inflammation are largely unknown.



DIFFERENTIAL DIAGNOSIS

- Diseases primarily affecting lung parenchyma. Rule out infectious pneumonia (toxoplasmosis, FIP, bacterial pneumonia, histoplasmosis).
- *Dirofilaria immitis* (heartworm) and primary lung parasites (*Aelurostrongylus abstrusus*, *Capillaria aerophila*, and *Paragonimus kellicotti*).
- Primary or metastatic neoplasia also similar in clinical, and occasionally, radiographic appearance.
- Primary cardiac disease may appear clinically and radiographically similar in certain instances, but these cats typically do not have a history of cough or have tracheal sensitivity on physical examination.
- Idiopathic pulmonary fibrosis may present clinically and diagnostically very similar to feline bronchitis.



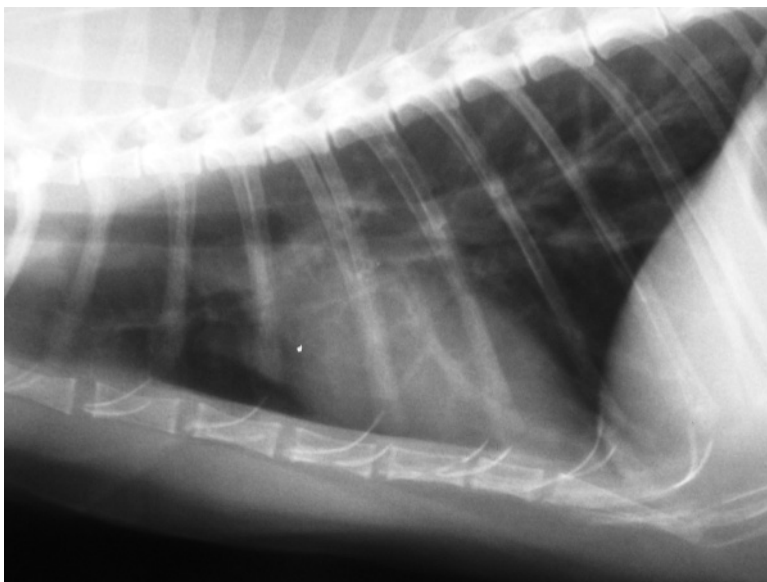
DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Frequently normal
- Less than 40 percent of cats with allergic airway disease have a peripheral eosinophilia. Peripheral eosinophilia is more common with parasitic infection or eosinophilic pulmonary granulomatosis.

Other Laboratory Tests

- Fecal exams—flotation examination for *Capillaria*; sedimentation for *Paragonimus*, Baermann technique for *Aelurostrongylus*. False-negatives occur.
- Heartworm testing—both antigen and antibody test recommended
- Pulmonary lung function testing—available in select academic institutions or specialty practices. Increased airway resistance is the classic finding; affects expiratory parameters more than inspiratory.
- RAST or intradermal skin testing—a correlation between skin and respiratory allergies has not been documented at this time.
- Feline proBNP—may aid in excluding cardiac disease as a cause of labored breathing and heighten suspicion of bronchitis



■ **Figure 32.1** Lateral thoracic radiograph of a cat with bronchitis. Note the bronchiolar thickening, also known colloquially as “donuts” and “tram lines,” and hyperinflation of the diaphragm.

Imaging

Radiography

- Classically, diffuse bronchial wall thickening and interstitial pattern (Figures 32.1 and 32.2)
- Patchy alveolar pattern can be seen as well.
- The severity of radiographic changes does not necessarily correlate with clinical severity or duration.
- Hyperinflation of lung fields—characterized by a flattened and caudally displaced diaphragm, an increase in the distance between the heart and diaphragm or extension of the lungs to the first lumbar vertebrae.
- Collapse of the right middle lung lobe has been reported with a frequency of 11 percent (Figure 32.3).
- Pulmonary lobar arterial enlargement is suspicious for heartworm disease.

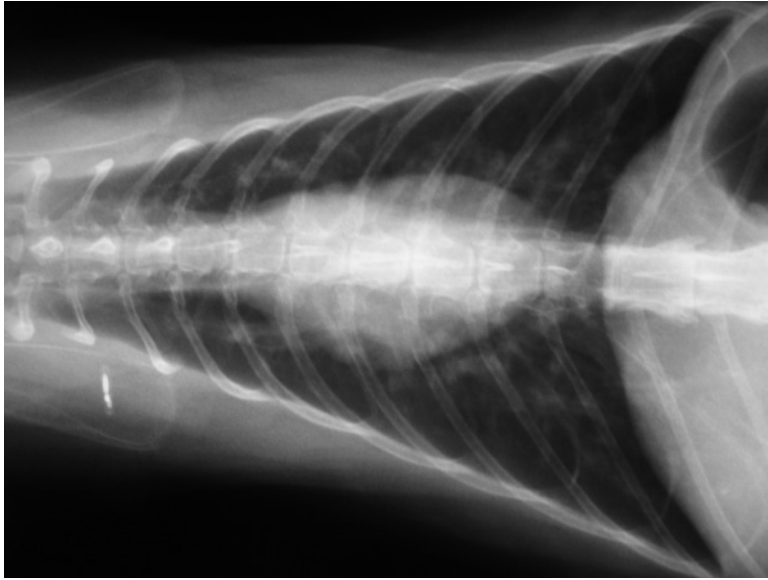
Echocardiography

- May be useful when evaluating for the possibility of heartworm disease or pulmonary hypertension secondary to chronic lung disease

Diagnostic Procedures

Transoral Tracheal Wash

- Use a sterile endotracheal tube and polypropylene catheter for obtaining a cytologic sample; this allows for sampling of airway fluids at the level of the carina.



■ **Figure 32.2** Ventrodorsal thoracic radiograph of a cat with bronchitis. Note the bronchiolar thickening, also known colloquially as "donuts" and "tram lines," and hyperinflation of the diaphragm.



■ **Figure 32.3** Ventrodorsal thoracic radiograph of a cat with bronchitis and atelectasis of the right middle lung lobe. This may be mistaken in some cases for aspiration pneumonia. Note the thickened bronchiolar markings which are supportive of bronchitis, rather than aspiration pneumonia.

- Does not allow for visualization of the lower airways or selective sampling of diseased lung.

Bronchoscopy/Bronchoalveolar Lavage

- Allows for visualization of trachea and bronchi. Excessive amounts of thick mucus are common with bronchitis. Mucosa of the airways is typically hyperemic and edematous.
- Biopsy or endoscopic brushing possible, although typically not needed with cases of bronchitis
- BAL should be performed during bronchoscopy; this allows for sampling of airway fluids from areas that appear most affected.

Cytology

- Eosinophils and neutrophils are most prominent cell types. A mixed cell population occurs in about 21 percent of cats.
- In one study, 22 percent of cats had normal cytology (macrophages predominated).
- Up to 30 percent eosinophils on BAL cytology can be found in normal cats. Parasitic and heartworm infections will have high percentages of eosinophils on cytology (Table 32.1).

Bacterial Cultures

- Quantitated cultures are recommended. Significant bacterial colony counts are uncommonly obtained in FBD. Significant bacterial growth on a quantitative culture is suggested to be >100 to 300 cfu/ml.
- *Mycoplasma* has been isolated from 21 to 44 percent of cats with FBD and was not isolated from healthy cats. Its role in bronchitis remains controversial.

TABLE 32.1 Mean (\pm SD) differential cell counts from bronchoalveolar lavage fluid obtained from normal cats in two independent studies

| Study | Padrid et al | King et al |
|--------------------------------|------------------|-------------------|
| Number | 24 | 11 |
| Total cell count/ml | 303 (\pm 126) | 241 (\pm 101) |
| % Macrophages | 64 (\pm 22) | 70.6 (\pm 9.8) |
| % Polymorphonuclear leukocytes | 5 (\pm 3) | 6.7 (\pm 4) |
| % Eosinophils | 25 (\pm 21) | 16.1 (\pm 6.8) |
| % Lymphocytes | 4 (\pm 3) | 4.6 (\pm 3.2) |
| % Mast cells | <1 (\pm <1) | Not reported |
| % Epithelial cells | 2 (\pm 2) | Not reported |
| % Goblet cells | <1 (\pm <1) | Not reported |

Biopsy

- Keyhole biopsy typically not indicated because of the invasiveness of the procedure. Rarely will the results alter the course of therapy, although they can help differentiate between idiopathic pulmonary fibrosis and bronchitis.

Pathologic Findings

- Histologic findings consistent with FBD include hyperplasia/hypertrophy of goblet cells, airway smooth muscle thickening, epithelial erosion, and inflammatory infiltrates.



THERAPEUTICS

Drug(s) of Choice

Emergency Treatment

- Combine the use of oxygen and a parenteral bronchodilator. A sedative often aids in decreasing anxiety associated with hypoxia. A short-acting parenteral corticosteroid may also be required. Patient manipulation should be minimized in order to avoid worsening respiratory distress.
- Injectable terbutaline (0.01 mg/kg IV or SQ). You can repeat this dose if no clinical improvement (decrease in respiratory rate or effort) in 20 to 30 minutes.
- Dexamethasone sodium phosphate (0.25–0.5 mg/kg, given IV or SQ). Can repeat if no improvement visible within 20 to 30 minutes. Prednisolone sodium succinate (Solu-Delta-Cortef) can also be used (50–100 mg IV).
- Butorphanol tartrate (0.4 mg/kg IV or IM) can be used for sedation. Also consider buprenorphine at (0.01 mg/kg) or acepromazine (0.001–0.05 mg/kg).

Long-Term Management

Corticosteroids

- Decrease inflammation
- Oral treatment is preferred over injectable because doses and duration can be more closely monitored.
- Prednisolone: 0.5 to 1 mg/kg PO every 12 hours. Begin to taper dose (50 percent each week) after 2 weeks if clinical signs have improved. If clinical signs resurface, dose should be increased again to 0.5 to 1 mg/kg PO every 12 hours. Maintenance therapy: 0.5 to 1 mg/kg PO every 24 to 48 hours. Some patients may be able to use steroids on a seasonal basis only.
- Dexamethasone sodium phosphate—used mainly for an acute crisis
- Longer-acting parenteral steroids (Vetalog or Depomedrol) should be reserved for situations where owners are unable to administer oral medication on a routine basis.



■ **Figure 32.4** Inhalation therapy with a metered dose inhaler and face mask in a cat with lower airway disease.

Inhaled Corticosteroids

- Newer therapy—requires a form-fitting facemask, spacer, and MDI (Figure 32.4). Veterinary brands include Aerokat (Trudell medical) or Nebulair (DVM pharmaceuticals).
- The most commonly used corticosteroid used in cats as an MDI is fluticasone propionate (Flovent). The 220- μ g or 110- μ g Flovent MDI is recommended (2 actuations, 7–10 breaths every 12 hours) along with other bronchodilators and oral corticosteroids, depending on the severity of clinical signs. One study has shown the 44- μ g MDI to be efficacious in decreasing BAL eosinophil counts in experimentally induced asthma. The 44- μ g Flovent MDI is only recommended after it has been established that inhalant corticosteroids are efficacious for that individual patient.
- Flovent is used for long-term control of airway inflammation. Takes 10 to 14 days to reach peak effect; during this time oral steroids should be used concurrently
- It has been shown that there is some suppression of the hypothalamic-pituitary axis in cats with the use of inhaled corticosteroids. Systemic side effects appear to be significantly less than with parenteral or oral medications.
- Methylxanthines (i.e., theophylline and aminophylline)—inhibit smooth muscle constriction. The pharmacokinetics of aminophylline would suggest that it is unlikely to be an effective treatment. Sustained-release theophylline formulations are often recommended, however the pharmacokinetics can vary greatly depending on the brand. The most recent recommended brands (Inwood brand at 10–15 mg/kg PO once a day) are becoming increasingly difficult to obtain.
- β_2 agonists (i.e., terbutaline, albuterol)—inhibit smooth muscle constriction. Injectable terbutaline is most helpful in a distressed animal (0.01 mg/kg SQ or IV). Oral terbutaline dose is one-fourth of a 2.5-mg tablet PO every 12 hours. The pharmacokinetics of oral terbutaline in cats is unknown. Initial albuterol dose is 20 μ g/kg PO every 12 hours; it can be increased to 50 μ g/kg PO every 8 hours.

Inhaled Bronchodilators

- Albuterol is the preferred inhalant bronchodilator therapy in cats, providing immediate relief of bronchoconstriction—its effect lasts less than 4 hours. Recommended as

adjuvant therapy in moderately to severely affected cats (every 12–24 hours) or during respiratory distress.

Anthelmintics

- They are routinely recommended for cats with clinical signs of FBD and airway cytology that is predominantly eosinophilic. Parasitic bronchitis can be difficult to diagnose based on airway cytology and fecal examination; empirical therapy is indicated with appropriate clinical signs and geographic location.
- Appropriate medication will depend on specific parasite suspected in the geographic region. Consider fenbendazole, ivermectin, or praziquantel.

Antibiotics

- Use should be based on a positive quantitative culture. Choice of antibiotic therapy is based on susceptibility testing.

Contraindications

- β_2 antagonists (e.g., propranolol) are contraindicated because of their ability to block sympathetically mediated bronchodilation.

Precautions/Interactions

- Bronchodilators may exacerbate underlying cardiac disease.
- Long-term use of steroids increases risk of development of diabetes mellitus and predisposes to immunosuppression.
- Use of corticosteroids in cats may unmask occult cardiomyopathy and precipitate congestive heart failure.
- Fluoroquinolones decrease the metabolism of methylxanthines in dogs, although this has not been investigated in cats. Consider decreasing the dose of methylxanthine by 50 percent when used concurrently with a fluoroquinolone. Watch for toxic side effects of the methylxanthine (e.g., vomiting, diarrhea, tachycardia).

Alternative Drugs

Cyproheptadine

- Serotonin antagonist. Has been shown in vitro to inhibit airway smooth muscle constriction in cats with experimentally induced asthma and should be used only in patients refractory to other therapy.

Cyclosporine (Neoral or Gengraf)

- Give 2.5 to 5.0 mg/kg every 12 hours; monitor cyclosporine levels.
- May be helpful in patients refractory to bronchodilator and corticosteroid therapy
- Leukotriene inhibitors or receptor blockers
- No evidence to support the use of these drugs in FBD

Activity

- Usually self-limited by patient

Diet

- Calorie restriction for obese cats

Appropriate Health Care

- Removal of patient from the inciting environment may help.
- Patient should be hospitalized for an acute crisis of respiratory distress.

Nursing Care

- Oxygen therapy and sedatives may help in an acute crisis. Minimize manipulation during a crisis in order to lessen stress and oxygen needs of the animal.



COMMENTS

Client Education

- Most causes of bronchitis are chronic, progressive diseases.
- Do not discontinue medical therapy when clinical signs have resolved; subclinical inflammation within the lungs is common and can lead to progression of disease.
- Lifelong medication and environmental changes may be necessary.
- Some clients can be taught to give terbutaline subcutaneously and corticosteroid injections at home for a crisis situation.

Patient Monitoring

- Owners should watch for and report any increase in coughing, sneezing, wheezing, or respiratory distress. Medications should be increased appropriately if clinical signs recur.
- Follow up radiographs are helpful in the first weeks after initial diagnosis to evaluate improvement with medical therapy.
- Long-term use of corticosteroids will require blood glucose monitoring every 3 to 6 months to screen for diabetes mellitus. Urinary tract infections can occur owing to immunosuppression. Owner should watch for signs of PU/PD that may indicate diabetes mellitus or renal disease.

Prevention/Avoidance

- Eliminate any environmental factors that may trigger a crisis situation (see Risk Factors/Causes).
- Change furnace and air conditioner filters on a regular basis.
- Consider dust-free litters.

Possible Complications

- Refractory cases or untreated acute episodes can be life threatening.
- Right-sided heart disease may develop as a result of long-term bronchitis.

Expected Course and Prognosis

- Long-term therapy should be expected.
- Most cats do well if recurrence of clinical signs is carefully monitored and medical therapy appropriately adjusted.
- A few cats will be refractory to treatment; these carry a much worse prognosis.

Associated Conditions

- Cor pulmonale can be a sequela to chronic lower airway disease.

Pregnancy/Fertility/Breeding

- Glucocorticoids are contraindicated in the pregnant animal. Bronchodilators should be used with caution.

Synonyms

- Allergic bronchitis, chronic obstructive pulmonary disease, asthmatic bronchitis, feline lower airway disease, extrinsic asthma, eosinophilic bronchitis, immune-mediated airway disease

Abbreviations

- BAL: bronchoalveolar lavage
- BNP: brain natriuretic peptide
- FBD: feline bronchopulmonary disease
- FIP: feline interstitial pneumonia
- IM: intramuscularly
- IV: intravenously
- MDI: metered-dose inhaler
- PO: by mouth
- PU/PD: polyuria/polydipsia
- RAST: radioallergosorbent testing
- SQ: subcutaneously

Suggested Readings

- Dye, JA, McKiernan, BC, Rozanski, EA, et al. Bronchopulmonary disease in the cat: historical, physical, radiographic, clinicopathologic, and pulmonary functional evaluation of 24 affected and 15 healthy cats. *J Vet Intern Med* 1996;10:385–399.
- Kirschvink, J, Leemans, J, Delvaux, F, et al. Inhaled fluticasone reduces bronchial responsiveness and airway inflammation in cats with mild chronic bronchitis. *J Fel Med and Surg* 2006;8(1): 45–54.

Moise, NS, Wiedenkeller, D, Yeager, AE, et al. Clinical, radiographic, and bronchial cytologic features of cats with bronchial disease: 65 cases (1980–1986). *J Am Vet Med Assoc* 1989;194(10):1467–1473.

Padrid, PA. Feline asthma. *Vet Clin North Am* 2000;30(6):1279–1293.

Padrid, PA, and Koblik, PD. The techniques used to diagnose feline respiratory disorders. *Vet Med* 1990;Sept:955–985.

Internet Resources

www.Aerokat.com—Internet source for ordering facemasks and spacers for inhalant therapy.

www.fritzthebrave.com—good source for clients to learn about feline bronchitis and research the possibility of inhaled medications in their cat.

Author: Carrie J. Miller

Feline Panleukopenia (FPL)



DEFINITION/OVERVIEW

- FPL is the common term used to describe a systemic, immunosuppressive disease of cats caused by highly contagious FVP.



ETIOLOGY/PATHOPHYSIOLOGY

- FPL virus (also FPV) is a single-stranded DNA virus.
- Because FVPs are contagious and resilient to destruction, the virus is found worldwide and continues to pose a significant threat to all members of the family *Felidae*.
- The high degree of seroprevalence in unvaccinated, healthy cats (75 percent) suggests that exposure rates are high, but most clinical infections are subclinical.
- Transmission of virus can occur following direct cat-to-cat contact as well as following indirect, oral contact with contaminated fomites (e.g., litter trays, hands, feeding dishes, cages, bedding).
- Infected cats usually shed virus for 1 to 2 days, however, recovering cats may shed virus in feces and urine for as long as 6 weeks.
- The ability of the virus to persist in the environment for sustained periods, rather than shedding, explains how the virus is maintained in the population.
- Virus undergoes initial replication in oropharyngeal lymphoid tissue within the first week post-infection then disseminates via plasma to virtually all body tissues, particularly those with high mitotic activity (e.g., the gastrointestinal tract). Damage to intestinal crypt epithelium culminates in malabsorptive disorders and diarrhea.
- Virus replication in the CNS can occur subsequent to in utero infection of healthy queens.
- FPV can infect fetal CNS tissues subsequent to vaccination of pregnant queens with MLV vaccine.
- Neonates vaccinated with MLV FPV vaccine prior to 4 weeks of age can experience vaccine virus dissemination and replication in the CNS. Viral DNA can be found in optic nerves, retina, and cerebellum.
- Cerebellar hypoplasia in kittens can be caused by FPV infection and MLV virus.
- Prenatal and neonatal infections have been associated with feline myocarditis and cardiomyopathy.



SIGNALMENT/HISTORY

- Most infections are subclinical, however severe clinical illness caused by FPV is most common among young kittens.
- Mortality is greatest between 3 and 5 months of age.
- FPV is also regarded as a cause of “fading kitten” syndrome (death occurring after birth but before weaning). The course of infection is acute with most deaths occurring as early as 12 hours to 5 days post-infection.
- Cats that survive acute illness for more than 5 days have a better prognosis for survival with supportive care.
- Clinical signs of inappetence and lethargy, followed by vomiting within 2 to 3 days.
- No gender or breed predisposition for FPV infection.
- Outbreaks of FPV have been reported in adult cats, particularly in high-density housing environments where seroprevalence can be particularly low (e.g., shelters, rescue groups).



CLINICAL FEATURES

- High fever (104°–107° F)
- Dehydration
- Evidence of vomiting may be present on the hair coat around the face.
- Diarrhea is uncommon and, when seen, usually occurs in the later stages of infection.
- Affected cats may resist abdominal palpation; palpation of thickened (rope-like consistency) intestines and enlarged mesenteric lymph nodes is characteristic.
- If treatment is delayed, cats may become profoundly lethargic or comatose, dehydrated, and hypothermic.
- Death attributed to secondary bacterial infection, DIC, or severe dehydration is common among kittens with acute, untreated FPV infection.
- Kittens infected in utero or vaccinated early in life with MLV FPV vaccine (<4 weeks of age) may manifest neurologic signs: ataxia, incoordination, and intention tremors typically associated with cerebellar hypoplasia. Affected kittens walk with a wide stance and a characteristic hypermetric gait. Neurologic manifestations are typically absent when the cat is at rest.



DIFFERENTIAL DIAGNOSIS

- “Fading kitten” syndrome
- Acute gastrointestinal toxicity (e.g., salmonellosis)
- Intussusception
- Septicemia

- Feline leukemia virus infection
- Feline immunodeficiency virus infection
- Linear foreign body



DIAGNOSTICS

Complete Blood Count

- Severely affected kittens may have total white blood cell counts between 50 and 3000 cells/ μ L.
- Less severely affected cats may have counts between 3000 and 7000 cells/ μ L.
- Cats that recover from acute FPV infection will manifest rebound leukocytosis with white blood cell counts exceeding 30,000 cells/ μ L.
- Anemia and thrombocytopenia are less common; variable laboratory findings.

Biochemistry

- No specific biochemical abnormalities occur in cats with FPL.

Serology

- Serological testing (virus neutralization is recommended) and virus isolation for the diagnosis of FPL are available from selected laboratories but these methods offer little value in the clinical setting due to the short clinical course.
- Serological testing is generally reserved for assessment of a protective immune response in vaccinated or exposed cats.

Enzyme-Linked Immunosorbent Assay

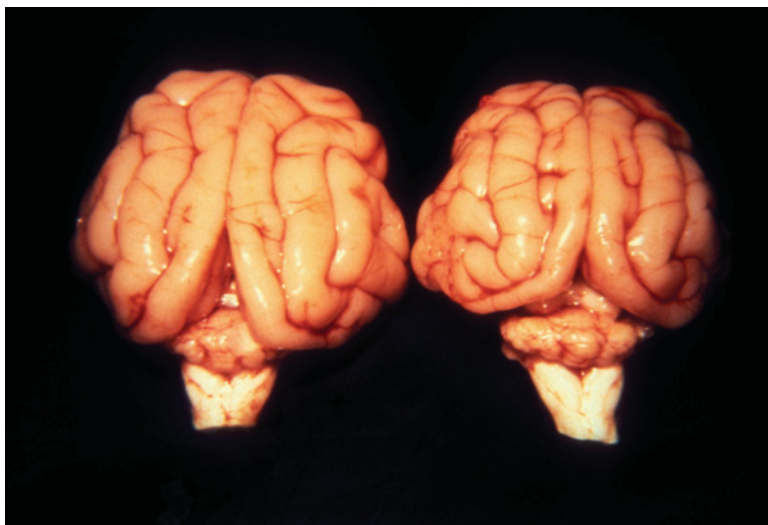
- ELISA-based canine parvovirus test for the presence of fecal antigen can be used in cats; however important limitations apply.
- The canine fecal antigen tests have not been standardized for use in cats with confirmed FPV infection.
- Furthermore, fecal shedding of FPV in cats may cease prior to the onset of clinical signs.

Histopathology

- Histopathology remains the confirmatory diagnostic test of choice for FPL.

Pathological Findings

- Gross pathological findings in cats that die of complications from FPV infection are minimal and usually limited to the small intestine (i.e., dilated bowel and serosal hemorrhages).



■ **Figure 33.1** Cerebellar hypoplasia in the brain of a kitten that was euthanized (*left*) because of neurologic signs compared to a normal cat brain (*right*).

- Significant histological findings center on changes in the crypt epithelium of the jejunum and ileum and lymphoid depletion.
- Cerebellar degeneration and hypoplasia (Figure 33.1) may be seen in kittens that experienced neonatal or in utero infection from FPV or MLV FPV vaccine.



THERAPEUTICS

- Parenteral fluid and electrolyte replacement therapy
- Insensible fluid loss should be replaced at the rate of 44 ml/kg per day using lactated Ringer's solution with supplemental potassium as indicated.

Nutritional Support

- Oral administration of food or liquid should be avoided during the acute clinical infection.

Antiemetic Therapy

- Plasma or blood transfusions are limited to patients that become anemic or hypoproteinemic (<5.0 g/dL).

General

- Antibiotic therapy (Ampicillin 22 mg/kg IV every 6 hours)
- B-vitamin combination

- Parenteral therapy should be continued at least until vomiting ceases and the cat resumes eating.
- Low-dose diazepam (2.5mg total) may be administered to promote eating in cats that have stopped vomiting and appear to be making a clinical recovery (interest in food, leukocytosis).

Early Vaccination

- Initial vaccination of kittens beginning at 4 weeks of age, and every 2 to 4 weeks thereafter until 16 weeks of age, is only recommended in group-housed cats where a reasonable risk of FPV exposure exists (e.g., shelter-housed kittens).
- Early vaccination is most likely to be effective in colostrum-deprived kittens.

Modified-Live Vaccine versus Inactivated Vaccine

- The author recommends use of MLV (non-adjuvanted) FPV vaccines in all cats with the exception of cats known to be positive for FeLV or FIV and kittens less than 6 weeks of age.
- In the event vaccination of a pregnant queen is indicated, use of an inactivated vaccine is recommended to reduce risk of vaccine virus replication in the CNS of unborn kittens (cerebellar hypoplasia).



COMMENTS

Client Education

- Before introduction of a new cat into a household where a cat/kitten has recently been diagnosed with, or died from, FPL, all cages, feeding bowls, floors, litter trays, and such should be thoroughly disinfected (fresh solution containing 1 ounce household bleach/gallon of water).
- Ideally, the facility should be isolated from cats for several days following disinfection before introducing a new cat.
- Prior to entry, any new cat/kitten should have received at least 2 doses of vaccine, with the last dose administered at least 2 weeks prior to introduction.

Controlling Outbreaks

- When administering inactivated (killed-adjuvanted) FPV vaccine to cats, a protective immune response is typically delayed until 2 to 3 weeks following the administration of the second dose. For this reason, inactivated (killed-adjuvanted) FPV vaccine has been implicated as a contributing factor in FPL outbreaks within multicat housing environments.
- In high-exposure risk environments, or in the face of an outbreak, kittens should be vaccinated with an MLV (non-adjuvanted) vaccine as early as 4 weeks of age and every 2 weeks thereafter as long as they reside in the facility.

Prevention/Avoidance

- In the United States both killed-virus (adjuvanted) and MLV vaccines (non-adjuvanted) are available for the prevention of disease caused by FPV.
- Vaccination provides excellent protective immunity and is recommended for administration to all kittens beginning as early as 6 weeks of age; a dose should be administered every 3 to 4 weeks until 15 to 16 weeks of age.
- Current vaccination recommendations include revaccination of all adult cats 1 year following the last dose in the initial series.
- Booster inoculations are recommended triennially thereafter.
- Vaccine approved for intranasal vaccination of cats against FPL (a trivalent vaccine for protection against herpesvirus and calicivirus as well as FPV) is available but is regarded as less effective than parenterally administered vaccines. All intranasal FPV vaccines are MLV products and should not be administered to kittens less than 4 weeks of age.

Abbreviations

- CNS: central nervous system
- DIC: disseminated intravascular coagulation
- ELISA: enzyme-linked immunosorbent assay
- FeLV: feline leukemia virus
- FIV: feline immunodeficiency virus
- FPL: feline panleukopenia
- FPV: feline parvovirus
- IV: intravenously
- MLV: modified-live vaccine

Suggested Reading

- Eleraky, NZ, Potgieter, LN, and Kennedy, MA. Virucidal efficacy of 4 new disinfectants. *J Am Anim Hosp Assoc* 2002;38:231–234.
- Greene, CE, and Addie, DD. Feline parvovirus infections. In: Greene CE, ed. *Infectious Diseases of the Dog and Cat*, 3rd ed., p. 78. St Louis: Saunders-Elsevier, 2006.
- Lamm, CG, and Rezabek, GB. Parvovirus infection in domestic companion animal species. *Vet Clin North Am Small Anim Pract* 2008;38:837–850.
- Neuerer, FF, Horlacher, K, Truyen, U, et al. Comparison of different in-house test systems to detect parvovirus in faeces of cats. *J Feline Med Surg* 2008;10:247–251.
- Richards, JR, Elston, TH, Ford, RB, et al. The 2006 American Association of Feline Practitioners feline vaccine advisory panel report. *J Am Vet Med Assoc* 2006;229:1405–1441.

Author: Richard B. Ford

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Fred W Scott

Feline Leukemia Virus Infection (FeLV)



DEFINITION/OVERVIEW

- FeLV is a retrovirus (γ -retrovirus) that causes immunosuppression and lymphocytic neoplasia in domestic cats.



ETIOLOGY/PATHOPHYSIOLOGY

- Horizontal transmission (oronasal or bite wounds); viral replication is in local lymphoid tissues, infected cells carry virus to target lymphoid tissues (i.e., thymus, spleen, and lymph nodes), at which time it is common to see fever, diarrhea, leukopenia, lethargy, and marked lymphadenopathy. Virus then infects salivary glands and mucosal glandular epithelium, which secrete virus for horizontal transmission, and bone marrow, which produces infected WBCs and platelets.
- Acute infection takes one of three courses: (1) strong immune response that eliminates virus; (2) virus sequestered and causes latency; (3) persistent viremia. If latent for >1year, reactivation is unlikely; viremia >16weeks or bone marrow infected (detected by IFA) likely viremic, persistently infected, and infectious for life.
- Tumor induction occurs when DNA provirus integrates into cat chromosomal DNA in specific oncogene regions.

Systems Affected

- Hemic/Lymphatic/Immune—anemia (regenerative or nonregenerative); blood cell dyscrasias; bone marrow and lymphoid neoplasias; immunosuppression with secondary infections or neoplasia; immune-mediated diseases (IMHA, glomerulonephritis, uveitis with immune complex deposition, polyarthrititis)
- Nervous—degenerative myelopathy, neuropathies (either direct neurotoxicity or secondary)
- Gastrointestinal—three clinical syndromes: FAE (i.e., vomiting/diarrhea, stomatitis, anorexia, weight loss); FAIDS (i.e., enterocolitis, crypt necrosis, villous atrophy, intractable diarrhea and weight loss); FPLS (i.e., severe leukopenia, enteritis, destruction of crypt epithelium that mimics FPV with concurrent anemia, may actually be a FPV-FeLV co-infection)

- Reproductive—fetal resorption, abortion, neonatal death; fading kitten syndrome (i.e., viremic kittens fail to nurse, severe dehydration, hypothermia, thymic atrophy, death within the first 2 weeks of life)
- All other body systems—immunosuppression with resulting secondary infections or neoplasia

Incidence/Prevalence

- One to 8 percent worldwide; prevalence in the United States has been decreasing since the 1980s due to testing and removal programs.

Geographic Distribution

- Worldwide



SIGNALMENT/HISTORY

Species

- Cats

Breed Predilection

- Mixed breed-to-pure breed ratio: 1.3:1

Mean Age and Range

- Prevalence highest between 1 and 6 years of age.

Predominant Sex

- Male-to-female ratio: 1.3:1 (outdoor-to-indoor ratio: 2.5:1)

General Comments

- Onset of FeLV-associated diseases may be delayed months to years after infection; clinical signs of virus are variable and nonspecific.
- Associated diseases—neoplastic or non-neoplastic; non-neoplastic or degenerative usually secondary to immunosuppression
- FeLV-induced immunodeficiency is clinically indistinguishable from that induced by FIV.

Historical Findings

- Outdoor cat
- Multicat household

Physical Examination Findings

- Depends greatly on presence of neoplastic or nonneoplastic disease and secondary infections
- Lymphadenopathy—mild to severe
- Upper respiratory tract—rhinitis, conjunctivitis, keratitis, or uveitis
- Gastrointestinal—persistent diarrhea (either primary or due to secondary infections)
- Oral—gingivitis, stomatitis, or periodontitis
- Integument—chronic recurrent skin or ear infections
- Neurologic—peripheral or central neuropathies
- Neoplasia—lymphoma, especially thymic and multicentric, occurs in up to 25 percent of cats who are positive for FeLV usually within 2 years of diagnosis; leukemias; fibrosarcomas due to co-infection with recombinant FeSV.

Risk Factors/Causes

- Feral or free-roaming cats
- Male
- Sexually intact
- Horizontal transmission via saliva or blood, usually by biting, grooming, sharing water bowls
- Vertical transmission via transplacental, transmammary, or grooming of neonates



DIFFERENTIAL DIAGNOSIS

- FIV
- Primary infections—viral, bacterial, fungal, or parasitic
- Neoplasia of nonviral origin



DIAGNOSTICS

Complete Blood Count/Chemistry/Urinalysis

- Anemia—regenerative or nonregenerative, often severe; occasionally see IMHA
- Lymphopenia
- Neutropenia—possibly in response to secondary infections
- Thrombocytopenia
- Urinalysis and serum chemistry profile—findings depend on systems affected and type of disease

Other Laboratory Tests

- General comments—no 100% accurate test
- ELISA/ICGA—detect free soluble FeLV-p27 antigen in plasma, serum, or whole blood; more sensitive than IFA at detecting early or transient antigenemia; a single positive test cannot predict persistent infections, retest in 12 weeks or test with IFA; false-positives more common with whole blood, not recommended to test saliva or tears.
- IFA—identify FeLV-p27 antigen in neutrophils and platelets of fixed smears of whole blood or buffy coat preparations (for leukopenic cats); positive result indicates active infection in bone marrow that can usually be detected by 3 weeks post-infection but may take up to 12 weeks to test positive; a positive result only indicates viral infection an not current illness, so it should be confirmed by another method and has no bearing on prognosis.
- Vaccinates are not detected by either ELISA/ICGA or IFA.
- Discordant results
 - Two ELISA/ICGA tests differ: perform IFA
 - Positive ELISA/ICGA and IFA: suggests persistent viremia and true positive
 - Positive ELISA/ICGA and negative IFA: repeat assay in 6 to 8 weeks
- PCR—detects viral RNA or DNA in blood, solid tissue, cell culture, or fixed samples; requires special equipment and expertise; can help determine status of cats with discordant ELISA/ICGA and IFA results or if suspicious of latent infections due to chronic conditions.

Imaging

- Thymic atrophy in fading kittens

Diagnostic Procedures

- Bone marrow aspiration or biopsy—indicated if nonregenerative anemia is present; rule out aplastic anemia versus anemia secondary to myeloproliferative disease.

Pathologic Findings

- Lesions depend on concurrent disease state and presence of neoplasia.



THERAPEUTICS

- Outpatient unless severe secondary infections or other conditions require hospitalization and further treatment
- Supportive care as needed

Drug(s) of Choice

- Zidovudine (Retrovir, AZT) 5 mg/kg PO, SQ every 12 hours; antiviral, possible clinical improvement but poor response *in vivo* than in cats infected with FIV; monitor for nonregenerative anemia, reduce dose compared to FIV treatment, do not treat cats with myelosuppression; other human antivirals are being studied but those with efficacy *in vivo* often have severe toxicity or are ineffective.
- Interferon—immunomodulatory and direct antiviral effect—human IFN α (Roferon) can be given for 6 to 7 weeks in high doses (10^5 to 10^6 IU/kg), after which neutralizing antibodies are generated. Oral administration (low dose: 15–30 U orally every 24 hours for 7 days on alternate weeks) may stimulate lymphoid tissue in the oral cavity with resulting systemic immunomodulation, but interferons are destroyed in the gastrointestinal tract so no measurable serum levels develop.
- Immunomodulatory therapy—nonspecific agents (i.e., *Acemannan*, *Staphylococcus* protein A, *Propionibacterium acnes*, and paraimmunity inducers) have showed equivocal results in clinical trials; nonspecific immune stimulation may increase viral replication and promote progression of disease, therefore it may not be recommended.
- Anemia—Blood transfusions may be necessary in severe anemia; suspect *Mycoplasma hemofelis* (formerly *Haemobartonella*) in all cats with regenerative hemolytic anemia and treat appropriately; EPO may be helpful with nonregenerative anemias.
- Topical bovine lactoferrin (40 mg/kg every 24 hours as needed) may be helpful for treatment of stomatitis
- Lymphoma—standard chemotherapy protocols
- Myeloproliferative disease and leukemias—more refractory to treatment.

Contraindications

- MLV vaccines may theoretically cause illness.

Precautions/Interactions

- Systemic glucocorticoids or other immunosuppressive drugs should be avoided unless a very compelling indication exists.
- Inactivated boosters to only core vaccines (RV and FRVCP) should be considered for routine vaccination; cats who are positive for FeLV may not be able to mount adequate immune response to rabies vaccination so more frequent boosters than usually recommended (e.g., every 6 months) must be considered, especially in cats allowed to go outside in areas with high rabies prevalence.
- Perioperative antibiotics are recommended for all surgeries and dental procedures.
- Virus lives for only minutes outside the host and is susceptible to all disinfectants (including common soap) so routine cleaning procedures will prevent transmission in the hospital. Viremic cats should be kept away from sick cats to protect them from infectious diseases, and under no circumstances should they be placed in an “isolation ward” with cats suffering from infections such as viral respiratory disease.

Diet

- Normal unless secondary conditions necessitate alternative foods

Surgical Considerations

- No specific surgical treatments; surgical removal of tumors if present, treat oral lesions appropriately.
- Intact cats who are positive for FeLV should be spayed or neutered to reduce stress associated with estrus/mating and decrease roaming and aggressive behaviors.



COMMENTS

Client Education

- Emphasize the importance of keeping cats who are positive for FeLV indoors to prevent spread of the virus and protect the positive cat from exposure to secondary infections.
- Warn owners that adult cats who are negative for FeLV have a 10 to 15 percent risk of infection if they have lived with a positive cat for several months. The negative cats should receive FeLV vaccination if the owner refuses to separate the housemates.
- Warn owners that cats who have FeLV may have a slower response to treatment of secondary conditions.

Patient Monitoring

- Biannual exams with CBC, oral examination, lymph node measurements, and body weight are recommended to evaluate for secondary diseases and myelosuppression; minimum annual chemistry profile and urinalysis should be performed, more frequent monitoring may be warranted if concurrent diseases exist.

Prevention/Avoidance

- Prevent interaction with infected cats.
- Quarantine and test new cats before introducing into multi-cat households/catteries.
- Vaccine—test cats before initial vaccination and do not vaccinate cats who are positive for FeLV; warn owners that cat may be infected if testing is not performed; efficacy controversial and none is 100 percent effective; risk of vaccine associated sarcomas with FeLV (and RV) vaccination is 0.1 to 0.01 percent overall, likely due to adjuvant, vaccinate low on left hind leg per AAFP recommendations.

Possible Complications

- Cats that are negative for FeLV that live with an infected cats have a fortyfold increased risk of lymphoma compared with cats who live in households that are negative for FeLV.

Expected Course and Prognosis

- Persistently viremic cats: >50 percent succumb to related diseases within 2 to 3 years after infection in multicat households, better survival rate in single-cat households

Associated Conditions

- Secondary infections
- Neoplasia—especially lymphoid, fibrosarcoma, other
- Immune mediated disease—IMHA

Age-Related Factors

- Neonatal kittens are most susceptible to persistent infection (70–100 percent); risk decreases with age: <30 percent susceptible by 16 weeks of age.

Zoonotic Potential

- None known but infection of human bone marrow possible in cell culture
- Potential transmission of secondary infections (e.g., *T. gondii*) to people who are immunocompromised

Pregnancy

- Transplacental transmission causes abortions, stillbirth, and fetal resorption; up to 20 percent of kittens may survive to become persistently infected adults; infected queen can also infect kittens by transmammary transmission, biting umbilical cord, or grooming kittens.
- Kittens born to a queen who is FeLV positive may test negative but usually seroconvert within weeks to a few months and should be retested.

Abbreviations

- AAFP: American Academy of Family Physicians
- AIDS: acquired immunodeficiency syndrome
- CBC: complete blood count
- ELISA: enzyme-linked immunosorbent assay
- EPO: erythropoietin
- FAE: FeLV associated enteritis
- FAIDS: Feline acquired immunodeficiency syndrome
- FeSV: feline sarcoma virus
- FIV: feline immunodeficiency virus
- FPLS: feline panleukopenia-like syndrome
- FPV: feline panleukopenia virus
- FRVCP: feline feline rhinotracheitis, calicivirus, panleukopenia
- ICGA: immunochromatographic assay
- IFA: immunofluorescent antibody
- IFN: interferon

- IMHA: immune-mediated hemolytic anemia
- MLV: modified-live virus
- PCR: polymerase chain reaction
- PO: by mouth
- RV: rabies vaccine
- SQ: subcutaneously
- WBC: white blood cell

Suggested Reading

Hartmann, K. FIV infection and related diseases. In: Ettinger, SJ, Feldman, EC eds., *Textbook of Veterinary Internal Medicine*, 6th ed., pp. 659–662. St. Louis: Saunders Elsevier, 2005.

Hartmann, K. FeLV and FIV. In: Bonagura, JD, ed., *Kirk's Current Veterinary Therapy XIV*, pp. 1278–1283. St. Louis: Saunders Elsevier, 2009.

Sellon, RK, and Hartmann, K. FIV infection. In: Greene, CE, ed., *Infectious Diseases of the Dog and Cat*, 3rd ed., 131–143. St. Louis: Saunders Elsevier, 2006.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Margaret C. Barr

Feline Infectious Peritonitis (FIP)



DEFINITION/OVERVIEW

- FIP, first discovered in the 1960s, is the term describing a complex systemic clinical syndrome of domestic, and certain nondomestic, cats resulting from infection with a virulent biotype of FCoV.



ETIOLOGY/PATHOPHYSIOLOGY

- The clinical syndrome called FIP is known to be caused by a virulent FCoV called FIPV.
- All FCoVs have the potential to cause FIP. However, not all cats with FIPV infection will develop clinical disease.
- Genetic susceptibility among certain breeds (e.g., Persian), and lines within breeds, may influence whether or not clinical illness develops.
- The pathophysiology of FCoV infection, and subsequent development of FIP, is complex and is not completely understood.
- FCoV infection occurs subsequent to fecal-oral transmission, commonly between a queen and her kittens, especially through contaminated litter.
- Infection via the respiratory tract has been suggested.
- FCoV replication within intestinal epithelium is rapid; viral shedding can occur in feces with 2 days of ingestion.
- FCoV infection may be subclinical (asymptomatic), may lead to diarrhea only, or may cause multisystemic disease.
- Most infections are subclinical.
- It is not possible to predict the outcome following infection.
- Multisystemic disease associated with FCoV infection is an immune-mediated disease leading to widespread vasculitis, a characteristic lesion of FIP.
- Once systemic dissemination of virus occurs, either of two clinical variations, effusive (“wet”) or noneffusive (“dry”) FIP, may result.
- Effusive FIP usually develops within 4 to 8 weeks following infection and typically develops in the peritoneal or pleural cavities. Effusion is the result of vasculitis, vessel destruction and the formation of pyogranulomata.

- Noneffusive FIP is a more chronic disease resulting from a partial cell-mediated immune response; clinical signs manifest months or years following initial infection.
- Why some cats never develop FIP following FCoV infection is not clear.
- Protection is generally associated with CMI, while a systemic humoral immune response is considered to be harmful or may predispose cats to severe disease following subsequent infection (antibody-dependent enhancement).



SIGNALMENT/HISTORY

- Transient vomiting or diarrhea may warrant veterinary attention during the earliest stages of clinical FIP (coronaviral enteritis).
- Although cats of any age may develop clinical FIP, about 50 percent are 2 years of age or younger.
- A history of having been group-housed (i.e., shelter, breeding cattery, rescue group) is common.
- Cats with effusive FIP may present for a distended abdomen (abdominal cavity effusion) or respiratory distress/tachypnea (thoracic cavity or pericardial effusion) (Figure 35.1).



■ **Figure 35.1** Abdominal distension in a 1-year-old cat diagnosed with effusive feline infectious peritonitis.

Risk Factors/Causes

- Risk of FIP is greatest among young cats (usually less than 2 years of age) housed in multicat households.
- Certain breeds (e.g., Persian), and lines within breeds, appear to be more likely to develop FIP subsequent to FCoV infection.
- Stress (e.g., recent surgery, rehousing, cluster housing) may be an important factor contributing to viral shedding and the signs of FIP in FCoV infected cats.



CLINICAL FEATURES

- Abdominal effusion (see Figure 35.1) or respiratory difficulty, associated with pleural cavity effusion or pericarditis, are among the most common presenting clinical manifestations of effusive FIP.
- Other nonspecific signs may include pallor, icterus, lethargy, palpable abdominal masses (adhesions or lymphadenomegaly), scrotal enlargement, and fever.
- Cats with noneffusive FIP typically present with vague clinical signs.
 - Abdominal palpation may reveal nodular irregularities on viscera or enlarged lymph nodes.
 - Several ocular abnormalities have been described in cats with FIP including iritis (color changes), anterior uveitis, keratic precipitates, and retinal detachment or hemorrhage.
 - Neurologic signs are reported in 25 to 33 percent of cats with noneffusive FIP. Nystagmus, ataxia, and seizures are among the most common neurologic signs reported.
 - FIP is not a recognized cause of “fading kitten syndrome” (i.e., death occurring between birth and weaning), but it is recognized as a cause of death among kittens after weaning.



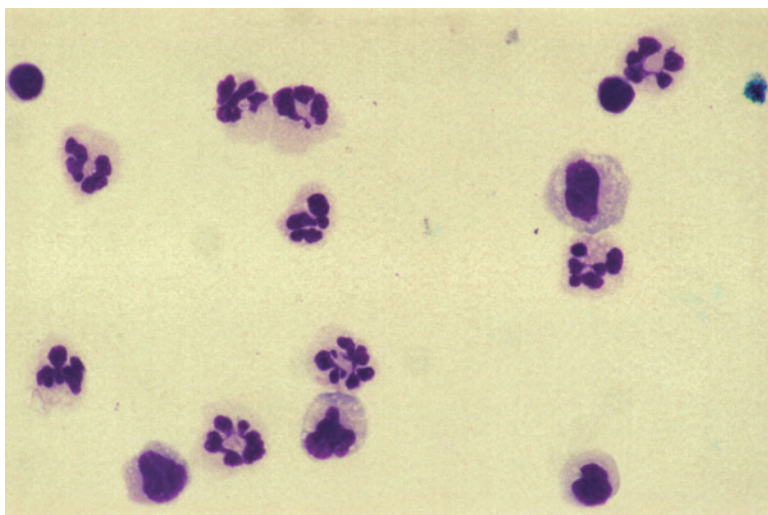
DIFFERENTIAL DIAGNOSIS

- The lack of specificity among the spectrum of clinical signs associated with FIP warrants testing any sick cat for FeLV antigen and FIV antibody.
- Pregnancy, abdominal neoplasia (lymphoma), hepatic failure, and hydronephrosis should be considered in cats presenting with abdominal distension.
- Cats presented with respiratory distress should be evaluated for cardiomyopathy, congestive heart failure, heartworm disease, pneumonia, lymphoma, and restrictive pleuritis.



DIAGNOSTICS

- Antemortem diagnosis of FIP, particularly noneffusive FIP, is difficult and requires a comprehensive assessment of the patient's history, clinical signs, and laboratory test results.
- Besides histopathology, there is no single diagnostic test that can confirm a diagnosis of FIP.
- Hematology may reveal lymphopenia and neutrophilia with a left shift and mild, nonregenerative anemia (hematocrit <30 percent).
- Hypoalbuminemia with hyperglobulinemia (albumin-to-globulin ratio ≤ 0.45) is highly suggestive of FIP in cats with associated clinical signs and is negative for FeLV and FIV.
- Approximately 75 percent of cats with noneffusive FIP have abnormal serum proteins, making this simple test an important diagnostic parameter.
- In cats with effusive FIP, fluid analysis is extremely useful in establishing a clinical diagnosis.
 - Physical appearance of the fluid collected from the abdominal or thoracic cavities reveals a viscous, yellow to straw-colored fluid that may form clots on standing and froths when shaken, not stirred.
 - Cytological assessment reveals a relatively hypocellular fluid (<5000 cells/ μL) consisting of neutrophils and macrophages (pyogranulomatous fluid) that is absent of bacteria or neoplastic cells (Figure 35.2).
 - Additionally, effusion with a high total protein (>3.5 g/dL) or an albumin-to-globulin ratio <0.45 is highly supportive of FIP.



■ **Figure 35.2** Cytological appearance of abdominal effusion from a cat (see Figure 35.1) with effusive feline infectious peritonitis; the pyogranulomatous effusion is characterized by the predominance of neutrophils and macrophages.

- Advanced diagnostics
 - Serologic testing for FCoV antibody is commonly used in practice, however this test is neither a consistent nor reliable indicator of FIP and should not be used as a single source diagnostic test.
 - Virus isolation from effusions of cats with FIP rarely yields positive results and, as such, availability is limited.
 - rtPCR has been successful in confirming the presence of FCoV in seronegative cats and detecting FCoV shedding. While this test is reported to have good sensitivity and specificity, rtPCR for FCoV does not specifically identify FIPV, the cause of FIP, and a positive test does *not* predict impending FIP in a healthy cat.
 - Recently, a commercially available rtPCR test for the detection of FCoV mRNA in circulating macrophages has become available (See www.vetmed.auburn.edu/index.pl/feline_infectious_peritonitis_virus for more information). The test is based on the fact that although avirulent FCoV can be found in peripheral blood, replication within macrophages, and expression of mRNA, is unique to FIPV.

Screening Healthy Cats

- Veterinarians may be requested to screen healthy cats for evidence of FIP. In such cases, it is reasonable to submit serum for FCoV antibody. Cats with a negative titer (usually less than 1 : 10 or 1 : 20) are unlikely to have been exposed to FCoV and are therefore acceptable candidates for use in breeding programs. However, the clinician must use a reliable laboratory that will perform titers to this level.

Pathological Findings

- Histopathology is the diagnostic test of choice in confirming FIP wherein pyogranuloma is the defining lesion. Kidney, spleen, and mesenteric lymph nodes are representative tissues likely to be affected in cats with FIP (Figure 35.3). Vasculitis is characteristically seen in the microvasculature of affected tissues.
- Pyogranulomatous mass lesions in the ileocecal colic junction have been reported in cats.



THERAPEUTICS

- In the absence of FCoV antiviral therapy, treatment centers on management of immune-mediated injury through judicious use of prednisolone (2–4 mg/kg per day PO once daily or divided into two doses; the dose can be reduced empirically every 10 to 14 days until an optimal response is achieved). Cats with FIP are expected to succumb from complications associated with the infection. Concurrent administration of antibiotics is indicated.
- Recombinant human IFN has been used in the United States as adjunctive therapy for cats with FIP. Because cats develop anti-IFN antibody, use of human IFN to treat



■ **Figure 35.3** Pyogranuloma on the cranial pole of a kidney from an adult cat that died of complications associated with noneffusive feline infectious peritonitis. Gross evidence of ischemic injury, subsequent to vasculitis, is present over the surface of the kidney.

FIP is no longer recommended. Recently, recombinant feline IFN-omega (currently not available in the United States) has been used concurrently with prednisolone to treat cats with FIP. However, benefits of supplemental IFN, without prednisolone, have not been established.

- Vitamins (B₁ [thiamine], B-complex, C [ascorbic acid], and E) as well as anabolic steroids and thromboxane synthetase inhibitors have been administered empirically as supportive treatment of cats with FIP. The clinical benefits associated with these products have not been defined.

Prognosis

- The prognosis of any kitten or cat with a confirmed diagnosis of FIP is poor.
- Cats with effusive FIP are not likely to live beyond a few weeks.
- Noneffusive FIP, however, is a more chronic clinical disease; with supportive treatment, affected cats may live for several months or years.
- Cats with neurologic disease caused by FIPV have a grave prognosis and are only expected to survive for days to weeks despite treatment.



COMMENTS

Client Education

- Beyond the prognosis, owners of cats with FIP who have additional, healthy cats in the household should be advised of the following:

1. Most cats that have been exposed to FCoV are likely to seroconvert within 18 to 21 days; however, a “positive” FCoV antibody titer does not define infection.
2. FCoV infection is common among group-housed cats but is not synonymous with FIP nor is it predictive of impending FIP.
3. Although FCoV is directly transmitted to cats, FIPV, the cause of FIP, is not generally considered to be a contagious virus.

Prevention/Avoidance

- Prevention of FIP centers on limiting exposure to FCoV, particularly among kittens.
- In breeding catteries, early weaning (by 5 weeks of age) and physical separation of kittens from adults (and their litter trays) have shown to be effective measures in limiting FCoV infection, and subsequent development of FIP, in kittens housed in multicat households.
- Immunization of susceptible cats and kittens against FIP has proved to be difficult. To date, only one vaccine has been licensed as an aid in the prevention of FIP. The vaccine is a modified-live virus approved for intranasal administration only. Although the vaccine is generally regarded as safe, efficacy has not been definitively demonstrated in field studies.
- Current feline vaccine guidelines stipulate that the FIP vaccine is “not generally recommended” on the basis that the vaccine has not been shown to consistently induce protective immunity.

Abbreviations

- CMI: cell-mediated immunity
- FCoV: feline coronavirus
- FeLV: feline leukemia virus
- FIP: feline infectious peritonitis
- FIPV: feline infectious peritonitis virus
- FIV: feline immunodeficiency virus
- INF: interferon
- mRNA: messenger ribonucleic acid
- PO: by mouth
- rtPCR: polymerase chain reaction for viral RNA

Suggested Reading

- Addie, DD, and Ishida, T. Feline infectious peritonitis: therapy and prevention. In: Bonagura, JD, and Twedt, DC, eds., *Kirk's Current Veterinary Therapy XIV*, p. 1295. St Louis: Saunders-Elsevier, 2009.
- Addie, DD, and Jarrett, O. Feline coronavirus infections. In: Greene, CE, ed. *Infectious Diseases of the Dog and Cat*, 3rd ed., p. 88. St Louis: Saunders-Elsevier, 200.

Andrew, SE. Feline infectious peritonitis. *Vet Clin North Am Small Anim Pract* 2000;30:987–1000.

Foley, JE, and Luttenegger, C. A review of coronavirus infection in the central nervous system of cats and mice. *J Vet Intern Med* 2001;15:438–444.

Foley, JE, Poland, A, Carlson, J, et al. Patterns of feline coronavirus infection and fecal shedding from cats in multiple-cat environments. *J Am Vet Med Assoc* 1997;210:1307–1312.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Fred W Scott

Feline Immunodeficiency Virus (FIV)



DEFINITION/OVERVIEW

- A retrovirus (genus *Lentivirus*) infection that causes immune suppression in domestic cats; same genus as HIV, the causative agent of AIDS in humans.



ETIOLOGY/PATHOPHYSIOLOGY

- Progressive disruption of normal immune function but otherwise not completely understood.
- Five viral subtypes (A, B, C, D, and E) that determine cell tropism and influence pathogenicity.
- Replicates in CD4⁺ and CD8⁺ lymphocytes, B-lymphocytes, macrophages, astrocytes, and microglia cells.
- Three clinical stages generally described: Acute—virus spreads from inoculation site to lymph tissues and thymus; clinically asymptomatic—duration varies but can last for years, depends on the pathogenicity of the infecting isolate and exposure to other pathogens; terminal (also called feline AIDS)—clinical signs reflect secondary infections, neoplasia, myelosuppression, and neurologic disease.
- Cell-mediated immunity—Over time there are changes in the CD4-to-CD8 cell ratio; initially CD4⁺ is suppressed, the immune response causes a rebound in CD8⁺ greater than preinfection levels, then over time both decrease.
- Humoral immunity—effected in terminal stages.
- Concurrent FeLV infection may increase pathogenicity of FIV.

Systems Affected

- Hemic/Lymphatic/Immune—Suppression of CD4⁺ and eventually CD8⁺T cells
- Renal/Urologic—Nephropathy
- Nervous—Behavioral changes, peripheral neuropathies, changes in normal sleep patterns, or seizures
- Other body systems—Secondary to immune suppression and secondary infections

Incidence/Prevalence

- United States and Canada—2 to 5 percent in healthy cat population; 4 to 24 percent in sick cats or cats with high risk (feral or free-roaming; male)

Geographic Distribution

- Worldwide; seroprevalence varies greatly and subtypes may be different in any given region.



SIGNALMENT/HISTORY

Species

- Cats

Mean Age and Range

- Prevalence increases with age at infection.

Predominant Sex

- Male two to four times more likely than females; demonstrate more aggression and roaming behaviors

General Comments

- Most often associated with immunosuppression and secondary infections
- FIV-induced immunodeficiency is clinically indistinguishable from that induced by FeLV.

Historical Findings

- Many are healthy; others have recurrent mild illness, particularly gastrointestinal or upper respiratory signs.

Physical Examination Findings

- May vary greatly depending on secondary infections
- Lymphadenopathy—mild to moderate
- Oral—gingivitis, stomatitis up to 50 percent of cases especially with concurrent calicivirus infection, periodontitis, or resorptive lesions
- Ocular—anterior uveitis (especially if concurrent *T. gondii* infection), pars planitis, conjunctivitis, glaucoma, chorioretinitis, retinal degeneration, and hemorrhages
- Integument—chronic recurrent skin or ear infections, bacterial, or fungal
- Upper respiratory tract—rhinitis, conjunctivitis, keratitis; often secondary concurrent herpes virus, calicivirus, or *T. gondii* infections

- Gastrointestinal—chronic diarrhea or primary inflammatory or secondary infectious (i.e., bacterial, fungal, or parasitic)
- Cachexia and fever, especially in terminal stages
- Neurologic—central and peripheral, in about 5 percent of cases, behavioral changes, changes in normal sleep patterns, peripheral neuropathies, or seizures
- Neoplasia—lymphoma (five times more likely than noninfected cats, mainly B cell) or other neoplasia

Risk Factors/Causes

- Feral or free-roaming cats
- Male
- Sexually intact
- Horizontal transmission via saliva or blood, usually by biting
- Vertical transplacental or transmammary transmission possible in vitro, rarely in vivo



DIFFERENTIAL DIAGNOSIS

- Primary infections—viral, bacterial, fungal, parasitic
- Toxoplasmosis—neurologic, ocular signs
- Neoplasia of nonviral origin



DIAGNOSTICS

Completed Blood Count/Chemistry/Urinalysis

- Hemogram—may be normal; lymphopenia, anemia, or neutropenia; neutrophilia may be present with secondary infections
- Serum chemistry profile and urinalysis—hyperproteinemia from hypergammaglobulinemia, otherwise typically normal unless secondary infections are present

Other Laboratory Tests

- Serologic testing
- Detects antibodies to FIV, seroconversion takes up to 12 weeks; antigen levels too low to detect.
 - ELISA—in-house and diagnostic laboratory tests are available for routine screening. False-positives and false-negatives are possible. Confirm all positive tests with western blot, especially in low-risk, healthy cats or if diagnosis will result in euthanasia.
 - Western (immuno) blot—used to confirm positive ELISA tests.
 - Kittens <6 months old may test positive due to the presence of maternal antibodies, retest at 8 to 12 months.

- Others:
 - Virus isolation—expensive, time consuming, requires expertise, making it impractical for routine diagnosis
 - PCR—assays available in the United States vary significantly in accuracy and are not reliable in differentiating vaccinates from infected cats. Sensitivity ranged from 41 to 93 percent. Specificity ranged from 81 to 100 percent in unvaccinated cats and 44 to 95 percent in cats vaccinated against FIV. Correct results were obtained in 58 to 90 percent of the 124 cats tested. All tests misidentified uninfected and infected cats. False-positive results by all laboratories were higher in cats vaccinated against FIV than in unvaccinated cats.
 - CD4⁺-to-CD8⁺ evaluation via flow cytometry can help to establish the extent of immunosuppression but is not diagnostic.

Pathologic Findings

- Lymphadenopathy—follicular hyperplasia and severe plasmacyte infiltration progressing to follicular involution as the disease progresses
- Lymphocytic plasmacytic infiltration in lymphoid tissues and other major organs (i.e., liver, spleen, kidney, skeletal muscle, and brain)
- Perivascular cuffing in muscle and brain, gliosis, neuronal loss, and reorganization
- Lymphoid interstitial pneumonitis characteristic of lentiviral infections in other species
- Bone marrow dysplasia, granulocytic hyperplasia, or marrow lymphoid aggregates
- Gastrointestinal inflammation, villous blunting, or pyogranulomatous colitis, similar to panleukopenia



THERAPEUTICS

Drug(s) of Choice

- Zidovudine (Retrovir, AZT) 5 to 10 mg/kg PO, SC every 12 hours; antiviral, monitor for nonregenerative anemia, virus can become resistant, reduce dose in cats with renal disease, do not treat cats with myelosuppression.
- IFN—immunomodulatory and direct antiviral effect—human IFN α (Roferon) can be given for 6 to 7 weeks in high doses (10^5 to 10^6 IU/k) parenterally, after which neutralizing antibodies are generated. Oral administration (low dose: 1–50 IU/kg every 24 hours) may stimulate lymphoid tissue in the oral cavity with resulting systemic immunomodulation, but INFs are destroyed in the gastrointestinal tract so no measurable serum levels develop.
- IGF—increases thymus size and T lymphocyte population in experimentally infected cats; no documented studies currently in naturally infected cats.
- Antibacterial and antifungal drugs as needed for secondary infections
- Anorexia—for short-term appetite stimulation: diazepam (Valium) 0.2 mg/kg IV or oxazepam (Serax) 2.5 mg/cat PO; for more prolonged appetite stimulation:

Mirtazapine (Remeron) 3.75 mg/cat PO every 3 days; anabolic steroids or megestrol acetate may have prolonged appetite stimulation and reverse cachexia, but efficacy in cats who are positive FIV unknown.

- Ocular manifestations such as glaucoma should be treated appropriately with standard therapies; anterior uveitis may be poorly responsive in the long term; Pars planitis often spontaneously resolves but may recur.
- Anemia—if underlying cause is not found, EPO may be used, 100 IU/kg SQ every other day until desired HCT is reached, then as needed to maintain the HCT.
- Oral lesions may be refractory to medical management, repeated dental prophylaxis and antibiotics may be palliative, and full-mouth extractions, including all roots, can help alleviate lesions. Avoid glucocorticoids in FIV-related stomatitis. AZT or topical bovine lactoferrin (40 mg/kg every 24 hours as needed) may be helpful.

Contraindications

- Griseofulvin can cause severe neutropenia allowing life-threatening secondary infections in cats who are positive for FIV.
- MLV may cause illness.
- Recombinant rHuG-CSF is contraindicated in neutropenic cats who are positive for FIV as it can increase viral load.

Precautions/Interactions

- Systemic glucocorticoids or other immunosuppressive drugs should be avoided unless a very compelling indication exists.
- Inactivated boosters to only core vaccines (RV and FVRCP) should be used; vaccination and antigenic stimulation may promote viral production, negating the advantage of preventing secondary infections. If cats who are positive for FIV are kept strictly indoors, the risk of secondary infections may be lower than the possible harmful effect of vaccination. Legal requirements for rabies vaccination may supersede these issues.
- Perioperative antibiotics are recommended for all surgeries and dental procedures.
- The virus lives for only minutes outside the host and is susceptible to all disinfectants (including common soap) so routine cleaning procedures will prevent transmission in the hospital. Viremic cats should be kept away from sick cats to protect them from infectious diseases, and under no circumstances should they be placed in an “isolation ward” with cats suffering from infections such as viral respiratory disease.

Alternative Drugs

- Immunomodulatory therapy—nonspecific agents (Acemannan, Staphylococcus protein A, *Propionibacterium acnes*, paramunity inducer) may relieve clinical signs in symptomatic cats, but nonspecific immune stimulation may increase viral replication and promote progression of disease, therefore may not be recommended.

Diet

- Normal unless secondary conditions necessitate alternative foods.

Surgical Considerations

- No specific surgical treatments; surgical removal of tumors if present, treating oral lesions appropriately.
- Intact FIV positive cats should be spayed/neutered to reduce stress associated with estrus/mating and decrease roaming and aggressive behaviors.

Appropriate Health Care

- Outpatient unless severe secondary infections require hospitalization and further treatment.

Nursing Care

- Appropriate for secondary infections and supportive care as needed.



COMMENTS

Client Education

- Educate client on course of disease including possibility of long-term good health and chronicity of illness if symptomatic.
- Emphasize the importance of keeping antibody positive cats, as well as negative cats in the household, indoors to prevent spread of the virus and protect the positive cats from exposure to secondary infections.

Patient Monitoring

- Biannual exams with CBC are recommended to evaluate for secondary diseases and myelosuppression, more frequent monitoring may be warranted if concurrent diseases exist.

Prevention/Avoidance

- Prevent interaction with infected cats.
- Quarantine and test new cats before introducing into multicat households/catteries. Transmission within stable social environments is rare.

Possible Complications

- Immunosuppression
- Recurrent bacterial or viral infections
- Neurologic disease including seizures

- Neoplasia
- Death

Expected Course and Prognosis

- Acute phase lasts several days to weeks, asymptomatic phase variable but may last many years, death occurring in about 18 percent of infected cats within the first 2 years (approximately 5 years after estimated time of infection). Length of terminal phase is often related to secondary infections, neoplasia, myelosuppression, and neurologic disease.

Vaccine

- Dual Subtype (A&D), inactivated adjuvanted whole virus vaccine (Fel-O-Vax FIV, Fort Dodge Animal Health)
- Vaccinates are indistinguishable from infected cats by current testing methods.

Associated Conditions

- Secondary infections
- Neoplasia—Especially lymphoid, also SCC, and others
- Age-related factors—Kittens may test positive due to maternal antibodies (viral or vaccinal).
- Potential transmission of secondary infections (e.g., *T. gondii*) to immunocompromised people

Pregnancy

- Transplacental and transmammary transmission is rare, but infected queen could infect kittens by biting umbilical cord or grooming kittens.

Abbreviations

- AIDS: acquired immunodeficiency syndrome
- CBC: complete blood count
- ELISA: enzyme-linked immunosorbent assay
- EPO: erythropoietin
- FeLV: feline leukemia virus
- FIV: feline immunodeficiency virus
- FVRCP: feline viral rhinotracheitis-calicivirus-panleukopenia vaccine
- HCT: hematocrit
- HIV: human immunodeficiency virus
- IGF: insulin-like growth factor
- INF: interferon
- IV: intravenously
- MLV: modified live virus

- PCR: polymerase chain reaction
- PO: by mouth
- rHuG-CSF: recombinant human granulocyte colony-stimulation factor (Filgastrim)
- RV: rabies vaccine
- SCC: squamous cell carcinoma
- SQ: subcutaneously

Suggested Reading

- Hartmann K. FIV Infection and Related Diseases. In: Ettinger SJ, Feldman EC ed., *Textbook of veterinary internal medicine*, 6th ed. St. Louis, MO: Saunders Elsevier, 2005:659–662.
- Hartmann K. FeLV and FIV. In: Bonagura JD, ed., *Kirk's current veterinary therapy XIV*, St. Louis, MO: Saunders Elsevier, 2009:1278–1283
- Sellon RK, Hartmann K. FIV Infection. In: Greene, CE ed., *Infectious diseases of the dog and cat*, ed 3. St. Louis, MO: Saunders Elsevier, 2006:131–143.
- Crawford PC, Slater MR, Levy JK. Accuracy of polymerase chain reaction assays for diagnosis of feline immunodeficiency virus infection in cats. *J Am Vet Med Assoc* 226:1503–1507, 2005.

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Acknowledgment to author of component in original in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Margaret C Barr

Feline Lower Urinary Tract Disease (FLUTD)



DEFINITION/OVERVIEW

- In approximately 65 percent of nonobstructed male and female cats with naturally occurring lower urinary tract disease, the exact cause(s) of hematuria, dysuria, pollakiuria, stranguria, and periuria are still unknown. After appropriate diagnostic evaluations, these cats are classified as having feline iLUTD or feline idiopathic cystitis.
- Feline iLUTD is an exclusionary diagnosis established only after known causes have been eliminated.
- Some cats with iLUTD exhibit findings similar to those observed in humans with *interstitial cystitis*, an idiopathic inflammatory disorder of the urinary bladder. These similarities have prompted the hypothesis that some cases of feline iLUTD are analogous to human interstitial cystitis; further studies are essential to prove or disprove this hypothesis.
- The terms *feline urological syndrome* and *FUS* have been commonly used to describe disorders of cats characterized by hematuria, dysuria, pollakiuria, stranguria, and partial or complete obstruction. Because these signs may be associated with any cause of lower urinary tract disease, these terms should be abandoned and replaced with more descriptive terminology pertaining to site of injury, cause(s), morphologic changes, or pathophysiologic mechanisms.



ETIOLOGY/PATHOPHYSIOLOGY

- Exact etiology(ies) are unknown, likely multifactorial.
- Quantitative or qualitative defects in surface GAGs and subsequent increased urothelial permeability have been hypothesized to be a causative factor.
- Stress may play a role in precipitating or exacerbating signs; neuroendocrine abnormalities identified in cats with chronic forms of iLUTD are indicative of increased activity of the sympathetic nervous system and diminished adrenocortical responsiveness.
- Experimental and clinical studies have implicated feline calicivirus as a potential etiological agent.

Systems Affected

Renal/Urologic

- Persistent urethral outflow obstruction results in postrenal azotemia.



SIGNALMENT/HISTORY

- Both males and females are affected.
- No breed predilection
- May occur at any age, but is most commonly recognized in young to middle aged adults (mean age 4.4 years)
- Uncommon in cats <1 year old and >10 years old
- No known genetic basis
- Common clinical signs include pollakiuria, hematuria, stranguria, periuria (urination in inappropriate locations), dysuria, and urethral outflow obstruction.

Risk Factors/Causes

- Stress—may play a role in precipitating or exacerbating signs; an unlikely primary cause
- Age—younger age is associated with an increased risk of recurrence of signs.
- Sex—males and female affected equally; however, neutered males and spayed females are at increased risk compared to intact animals.

Historical Findings

- Pollakiuria
- Hematuria
- Dysuria
- Stranguria
- Periuria—urinating in inappropriate locations
- Urinary outflow obstruction



CLINICAL FEATURES

- Periuria, pollakiuria, stranguria, and gross hematuria are the most common clinical signs observed in cats with nonobstructive idiopathic cystitis.
- Clinical signs subside within 5 to 7 days without therapy in up to 92 percent of cats with acute nonobstructive idiopathic cystitis.
- Signs may recur after variable periods of time and again subside without treatment. Approximately 40 to 50 percent of cats with acute idiopathic cystitis will experience one or more recurrences of signs within 1 to 2 years.

- Recurrent episodes of acute idiopathic cystitis tend to decrease in frequency and severity as the cats become older.
- Recurrent clinical signs in patients with idiopathic cystitis are often assumed to be recurrence of the original disease; however, recurrent signs may also be the result of a delayed manifestation of the original disease (e.g., spontaneous or iatrogenic urethral stricture), or onset of a different lower urinary tract disease associated with similar clinical signs (e.g., urolithiasis).
- A small subset of cats with iLUTD have persistent clinical signs that last for weeks to months or are frequently recurrent. These cats are classified as having iLUTD. Less than 15 percent of cats evaluated because of acute idiopathic cystitis will develop chronic forms of the disease.
- Physical examination—may reveal a thickened, firm, contracted, painful, bladder wall; may detect urethral plugs or uroliths by examination of the distal penis and penile urethra.



DIFFERENTIAL DIAGNOSIS

- Metabolic disorders including various types of uroliths and urethral plugs.
- Infectious agents including bacteria, fungal agents, and parasites.
- Trauma
- Neurogenic disorders including reflex dyssynergia, urethral spasm, and hypotonic or atonic bladder (primary or secondary).
- Iatrogenic diseases including those due to urethral catheters, indwelling urethral catheters (especially open systems), postsurgical catheters, reverse-flushing solutions, and urethrostomy complications.
- Anatomic abnormalities including urachal anomalies and acquired urethral strictures.
- Neoplasia (benign and malignant).
- Behavioral disorders resulting in periuria.
- Clinical signs may be confused with constipation.



DIAGNOSTICS

- No single test is diagnostic; feline iLUTD is an exclusionary diagnosis established only after known causes have been eliminated.
- Hematuria and proteinuria are common urinalysis findings. Initial episodes of iLUTD usually occur in the absence of pyuria and significant numbers of detectable bacteria.
- Quantitative urine culture—verifies absence of bacteriuria and excludes urinary tract infection; light microscopic examination of urine sediment is an unreliable method of detecting bacteriuria; collect urine specimens by cystocentesis to avoid contamination with organisms that normally inhabit the distal urethra.

- Survey radiography—may exclude uroliths or urethral plugs.
- Positive-contrast retrograde urethrocytography or antegrade cystography—may exclude urethral strictures, vesicourachal diverticula, and neoplasia.
- Double-contrast cystography—may exclude small or radiolucent uroliths, blood clots, and thickening of the bladder wall due to inflammation or neoplasia.
- Ultrasonography—may exclude uroliths in the urinary bladder.
- Urethrocytscopy—may reveal petechial submucosal hemorrhages (so-called glomerulations) on the surface of the urinary bladder; may exclude urethral strictures, ureteroliths, urocystoliths, blood clots, vesicourachal diverticula, and neoplasia.
- Biopsies obtained with urinary catheters, cystoscopes, or via surgery—may permit morphologic characterization of the inflammatory or neoplastic lesions; not routinely needed.

Pathologic Findings

- Mucosal ulceration and submucosal edema, hemorrhage, fibrosis, neovascularization, mastocytosis, and mononuclear inflammatory cell infiltration are common light microscopic lesions observed in the urinary bladders of cats with chronic iLUTD.
- Inflammatory cells may not be prominent in some forms of the disease, unless secondary bacterial infections have resulted from catheterization or perineal urethrostomy.



THERAPEUTICS

- Patients with nonobstructive lower urinary tract disease—typically managed as outpatients; diagnostic evaluation may require brief hospitalization
- Patients with obstructive lower urinary tract disease—usually hospitalized for diagnosis and management
- Short-term use of pharmacologic agents is considered for any patient with severe signs.
- Long-term dietary and environment management strategies are used to minimize the risk of recurrences.
- Long-term pharmacologic interventions are usually reserved for cats with more severe chronic forms of the disease in which dietary and environmental management strategies have failed to adequately control clinical signs or frequency of recurrences.
- Over 70 agents or procedures have been recommended for management of nonobstructive iLUTD in cats; fewer than 10 percent of these proposed treatments have been evaluated in controlled clinical trials. Debate surrounding the efficacy of various treatments is complicated by the self-limiting nature of clinical signs associated with the majority of cases of idiopathic cystitis. In this setting, any form of therapy might appear to be beneficial as long as it is not harmful.

Drug(s) of Choice

Anti-Inflammatory Agents and Analgesics

- Opioid analgesics—short-term opioid analgesic therapy for 24 to 72 hours may be of benefit in alleviating acute “flare-ups” of severe pollakiuria, dysuria, stranguria, and periuria in affected cats; butorphanol 0.2 to 0.4 mg/kg every 8 hours, PO for 1 to 3 days; buprenorphine 0.01 to 0.02 mg/kg every 6 to 12 hours, IM or SQ, buccally for 1 to 3 days. There have been no reports of controlled studies evaluating the efficacy and safety of short-term opioid analgesics for management of cats with idiopathic cystitis.
- Corticosteroids—no detectable effect on remission of clinical signs in cats demonstrated in controlled clinical trial; predispose to bacterial urinary tract infections, especially in cats with indwelling transurethral catheters.
- NSAIDs—safety and efficacy of NSAIDs in the treatment of cats with iLUTD have not been evaluated by controlled clinical trials. Pending further safety and efficacy studies, use appropriate caution when considering use of NSAIDs to treat feline idiopathic cystitis.

Amitriptyline and Other Antidepressants

- Amitriptyline—a tricyclic antidepressant and anxiolytic drug (with anticholinergic, antihistaminic, anti α -adrenergic, anti-inflammatory, and analgesic properties) reserved for treatment of cats with severe chronic iLUTD who have not responded to other forms of pharmacologic, dietary, and environmental management; suggested empirical dosage is 5 to 10 mg/cat every 24 hours given at night; may predispose to urine retention, bacterial urinary tract infection, and urolithiasis. We do not recommend amitriptyline for treatment of acute self-limiting episodes of iLUTD.
- Efficacy and safety of other tricyclic antidepressants, selective serotonin reuptake inhibitors, and anxiolytics have not been evaluated by controlled clinical trials.

Glycosaminoglycans

- Pentosan polysulfate sodium—a semi-synthetic low molecular weight heparin analogue that reinforces urothelial GAGs and reduces transitional cell injury. Oral pentosan polysulfate 50 mg every 12 hours PO may benefit some cats with chronic iLUTD. Results of controlled clinical studies evaluating the safety and efficacy of pentosan polysulfate have not been reported.
- Glucosamine/chondroitin sulfate—glucosamine, an amino sugar naturally produced in the body, is an important intermediate for the formation of GAGs. Chondroitin sulfate is one of the most abundant GAGs in the bladder surface GAG layer. No significant difference between the severity of clinical signs in cats treated with glucosamine and those treated with a placebo. The efficacy of oral glucosamine combined with chondroitin sulfate has not been evaluated by controlled clinical trials.

Anticholinergics

- Propantheline—a potent quaternary ammonium anticholinergic agent that minimizes the force and frequency of uncontrolled detrusor contractions; no difference in rate of recovery was observed between cats treated with propantheline and control groups.
- Oxybutynin chloride—a moderately potent anticholinergic agent with additional independent musculotropic relaxant and local anesthetic effects; efficacy of oxybutynin has not been evaluated by controlled clinical trials.
- Tolterodine—a moderately potent anticholinergic agent that may have a more pronounced in vivo effect on urinary bladder than oxybutynin; efficacy of tolterodine has not been evaluated by controlled clinical trials.

General

- Feline facial pheromone fraction F3—no detectable effect on remission of clinical signs in cats demonstrated in controlled clinical trial.
- Antimicrobials—no detectable effect on remission of clinical signs in cats demonstrated in controlled clinical trial.

Precautions/Interactions

- Cats with urethral obstruction and postrenal azotemia are at increased risk for adverse drug events, especially with drugs and anesthetics that depend on renal elimination or metabolism.
- Indwelling urethral catheters, especially when associated with fluid-induced diuresis or coadministration of corticosteroids, predispose patients to bacterial urinary tract infections.
- Tricyclic antidepressants (e.g., amitriptyline)—avoid short-term administration or abrupt discontinuation
- Coadministration of oxybutynin or tolterodine with other anticholinergic agents (e.g., amitriptyline)—may intensify adverse effects and should be avoided
- Phenazopyridine—a urinary tract analgesic; may result in methemoglobinemia and Heinz body anemia
- Methylene blue—a weak antiseptic agent; may result in Heinz body anemia

Diet

- Results of a nonrandomized, open, prospective study suggest that feeding moist rather than dry foods may minimize recurrence of signs.
- Management recommended for persistent crystalluria in patients at risk for formation of crystalline-matrix urethral plugs

Surgical Considerations

- Cystotomy to obtain biopsy specimens in patients with clinical finding consistent with iLUTD is not recommended.

- Cystotomy to lavage and débride the bladder mucosa as a form of treatment is not recommended.
- Do not perform perineal urethrostomies to minimize recurrent urethral obstruction without localizing obstructive disease to the penile urethra by contrast radiography.



COMMENTS

Client Educations

- Hematuria, dysuria, and pollakiuria—often self-limiting; subside within 5 to 7 days, but signs may recur unpredictably in approximately one-half of affected cats
- Lack of controlled studies that demonstrate efficacy of most drugs used to treat symptomatically
- Recurrent episodes of acute iLUTD tend to decrease in frequency and severity as the cats become older.

Patient Monitoring

- Males should be monitored for signs of urethral obstruction.

Prevention/Avoidance

- Feed moist diets
- Reduce environmental stress by minimizing changes in the home, maintaining a constant diet, providing opportunities for play and safe places to hide, refining cat-owner interactions, and managing conflict between cats

Possible Complications

- Urethral obstruction due to formation of urethral plugs—most common in male cats with concurrent crystalluria
- Vesicourachal diverticula—acquired vesicourachal diverticula often are self-limiting with resolution of clinical signs.
- Indwelling transurethral catheters—often cause trauma; predispose to ascending bacterial urinary tract infections
- Perineal urethrostomies—may predispose to ascending bacterial urinary tract infections and urethral strictures

Expected Course and Prognosis

- Hematuria, pollakiuria, and dysuria often are self-limiting in patients with most iLUTDs, subsiding within 5 to 7 days.
- Signs will recur unpredictably in approximately half of affected cats; the frequency of recurrence declines with advancing age.

Synonyms

- Feline idiopathic cystitis
- Feline sterile idiopathic cystitis
- Feline interstitial cystitis
- FUS

Abbreviations

- FUS: feline urological syndrome
- GAGs: glycosaminoglycans
- iLUTD: idiopathic lower urinary tract disease
- IM: intramuscularly
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Kruger, JM, and Osborne, CA. Management of nonobstructive feline idiopathic cystitis: principles, practices, and perspectives. In: Bonagura, JD, ed. *Kirk's Current Veterinary Therapy XIV*, 14th ed. pp. 944–950. Philadelphia: Saunders, 2008.

Authors: John M. Kruger, Carl A. Osborne, and Jody P. Lulich

Gastric Dilatation-Volvulus (GDV) Syndrome



DEFINITION/OVERVIEW

- GDV syndrome starts as a rotation of the stomach along its long axis that causes intragastric accumulation of gas.
- GDV results in a variety of life-threatening conditions that can include circulatory shock and SIRS.
- If left untreated, GDV leads to death.



ETIOLOGY/PATHOPHYSIOLOGY

- Severe gastric distention causes significant intraperitoneal pressure elevation, obstruction of the compliant caudal vena cava, decreased venous return and cardiac output, hypoxemia, microcirculatory injury and maldistribution of blood flow.
- Cytokine production, cellular dysfunction, and reperfusion injury following resuscitation can induce the SIRS and DIC. These consequences can culminate in multi-organ failure and death.

Systems Affected

Cardiovascular

- Translocation of fluid into the stomach and hemorrhage from rupture of the short gastric and epiploic vessels can cause significant hypovolemia.
- Hypoxemia, electrolyte disturbances, acid-base imbalances, and release of inflammatory cytokines and myocardial depressant factors can result in myocardial dysrhythmias (e.g., ventricular premature contractions).
- Pain is considerable; the sympathetic response can contribute to cardiovascular compromise; gastric distension and compression of the caudal vena cava can result in decreased return of blood to the right-sided heart, which ultimately results in decreased cardiac preload, stroke volume, cardiac output, and hypotension.

Gastrointestinal

- Gastric rotation and tearing of gastric blood supply cause reduced gastric blood flow and ischemia.

- Increased intraperitoneal pressure and decreased cardiac output reduces splanchnic blood flow.

Hemic/Lymphatic/Immune

- Bacterial endotoxin translocation through the disabled GI mucosal barrier into the lymphatics and bloodstream is expected.
- As the stomach rotates, it can pull at the short gastric vessels, cause a splenic torsion, or splenic ischemia or thrombosis.

Hepatobiliary

- Because the liver may be compromised from venous congestion and circulatory shock, bacteria may not be removed from the portal system, and can result in septicemia.

Respiratory

- Upper airway obstruction from regurgitation and aspiration of swallowed saliva can result in aspiration pneumonia.
- Decreased thoracic capacity from gastric distension and diaphragmatic compression can lead to hypoventilation and hypoxia.



SIGNALMENT/HISTORY

Risk Factors/Causes

- GDV can occur in any breed or species of animal, although it is most commonly seen in large breed dogs with increased thoracic depth to width ratio (e.g., Great Dane, Gordon and Irish setter, Weimeraner, standard poodle, basset hound, and Saint Bernard).
- Other characteristics that are associated with GDV include having a first-degree relative that suffered GDV and owner's perception of high-level stress in the dog.
- Additional factors thought to influence the formation of GDV include lean body condition, increasing age, large sudden drops in environmental temperature, feeding single large meals, overeating, small kibble size, elevated feeding bowls, postprandial exercise, anesthesia, and aerophagia.
- The addition of table food or canned food to the diet of large and giant breed dogs has been associated with a decreased incidence of GDV.

Historical Findings

- Common presenting complaints include "vomiting" or dry heaves and description of nonproductive retching, restlessness, increased salivation, and abdominal distension.
- Occasionally, straining to defecate or stretching will be described.



CLINICAL FEATURES

- Poor perfusion characterized by brick red or pale mucous membrane color
- Rapid or prolonged capillary refill time
- Weak or bounding pulse quality
- Tachycardia
- Hypersalivation
- Abdominal distension with gastric tympany (this may be hidden under the rib cage in some cases)
- Tachypnea with or without labored breathing
- Nonproductive retching
- Occasionally splenomegaly can be palpated.



DIFFERENTIAL DIAGNOSIS

- Gastric dilation without volvulus
- Food bloat
- Splenic torsion
- Intestinal volvulus
- Peritonitis
- Megaesophagus
- Infectious tracheobronchitis



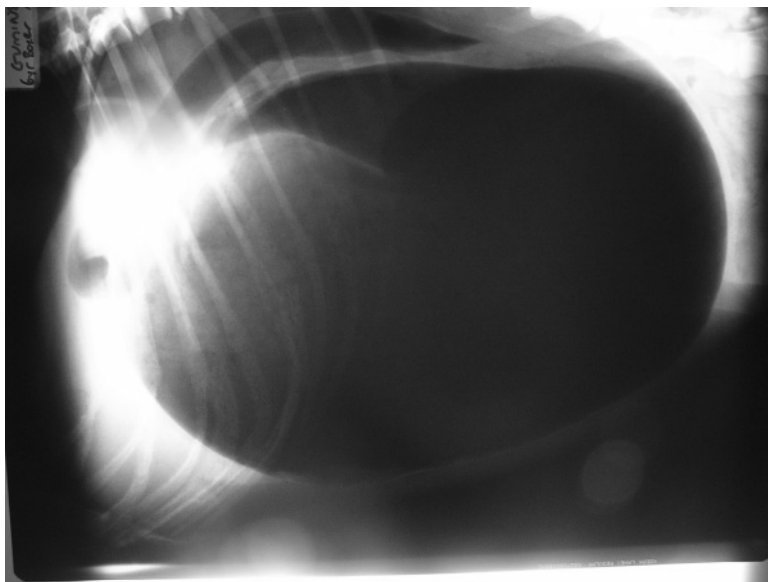
DIAGNOSTICS

Physical Examination

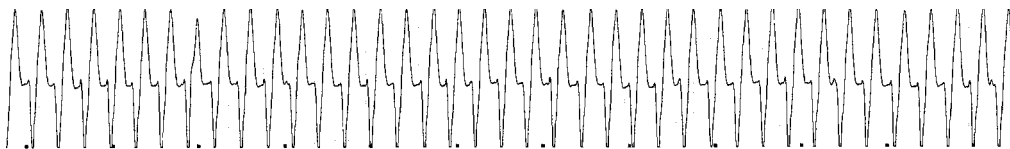
- The physical examination findings that lead to a suspicion of GDV are listed in the clinical features.

Radiographs

- A right lateral abdominal radiograph is usually the most diagnostic view for confirming the diagnosis (Figure 38.1). Typical radiographic signs include gas- or fluid-dilated stomach and displacement of the pylorus in a dorsocranial position causing compartmentalization or “Popeye arm” or “Smurf hat.”
- Occasionally a left lateral or dorsoventral abdominal radiograph is also needed.
- Ventrodorsal radiographs are not recommended because positioning can place extra pressure on the vena cava and additional compromise in venous return.
- The presence of gas within the gastric wall on radiographs may be observed when significant necrosis is present.



■ **Figure 38.1** Right lateral abdominal radiograph of a dog with gastric dilatation-volvulus with gas distension of the fundus and dorsocranial displacement of the pylorus, resulting in a demarcation between the two areas. This has been called “a Popeye arm” or a “Smurf hat” by some radiologists.



■ **Figure 38.2** Sustained unifocal ventricular tachycardia from a dog with gastric dilatation-volvulus.

Laboratory Analyses

- An immediate electrolyte panel venous blood gas, glucose and lactate levels are evaluated and abnormalities immediately addressed.
- Because GDV is considered an emergency surgical procedure, preanesthetic laboratory analyses that include a complete blood count, serum biochemistry profile, and prothrombin/activated partial thromboplastin times are indicated.

Cardiovascular Monitoring

- An electrocardiogram and blood pressure should be immediately evaluated at the time of presentation.
- It is not unexpected to discover a ventricular dysrhythmia caused by myocardial hypoxia and circulating cytokines (Figure 38.2).
- Hypertension is also not uncommon and usually corrects with fluid resuscitation and analgesia.

- When hypotension or bradycardia exists, severe to catastrophic shock may be occurring.

Pathological Findings

- Anemia and hypoproteinemia can occur with hemorrhage and blood loss into the damaged GI tract.
- Lactate level > 6.0 mmol/dL is a positive predictor of gastric necrosis and outcome.
- Thrombocytopenia and prolonged ACT, prothrombin time, and activated partial thromboplastin time are not unexpected and can be caused by consumption from hemorrhage or a systemic inflammatory processes. A significant coagulopathy with evidence of hemorrhage requires careful hemostasis during surgery and judicious use of synthetic colloids.
- Ventricular dysrhythmias can occur pre-, intra-, and postoperatively.
- Esophageal dilation is also a reversible problem that usually corrects spontaneously after gastric repositioning.

Surgical Findings

- Gastric rotation can occur in any direction.
- Most commonly, however, it rotates 180 to 270 degrees in a clockwise direction (as viewed from the caudal aspect of the patient when it is in dorsal recumbency).
- The pylorus initially moves ventral and to the left and ultimately rests in the dorsal left quadrant of the abdomen.
- Various degrees of gastric injury will be encountered, but most commonly, the cardia, up to the esophageal hiatus, and the greater curvature of the fundus of the stomach are affected.
- Changes can be minor, with only mild hyperemia seen, or major with black and ischemic gastric wall seen at the time of surgery.
- Peritoneal hemorrhage will most commonly occur from torn gastroepiploic and short gastric vessels.
- Additional intraoperative findings can include splenic enlargement or torsion, and pancreatic edema.



THERAPEUTICS

Drug(s) of Choice

Balanced Analgesia

- Pure μ -agonist opioids (such as fentanyl 5 μ g/kg IV followed by a continuous infusion of 3–5 μ g/kg per hour) are given with a benzodiazepine (such as midazolam or diazepam, 0.2 mg/kg IV).
- When possible, avoid opioids known to induce vomiting (i.e., morphine, hydromorphone)

- Lidocaine (1–4 mg/kg bolus, followed by 50–100 µg/kg per hour or 300 mg in 1 liter isotonic saline set at 2 ml/kg per hour) is used as an adjunctive analgesic or if a significant ventricular dysrhythmia develops.
- Opioids and lidocaine can be mixed in the same fluid bag for continuous infusion.

Antibiotics

- Perioperative broad-spectrum antibiotics such as a first-generation cephalosporin or ampicillin (20 mg/kg IV) should be administered.
- Based on the findings at the time of surgery, additional antibiotics are selected based on the need for anaerobes or resistant gram-negative coverage but are rarely required.

Gastric Decompression

Percutaneous Decompression/Trocarization

- If the stomach can be percussed behind the ribs, it should be decompressed.
- Percutaneous decompression is less stressful, less painful, and requires minimal assistance compared with orogastric intubation and decompression.
- Percutaneous decompression should be performed by clipping the fur over the most tympanic part of the abdomen. Next the clipped area should be aseptically scrubbed, then a large-bore (14–16-gauge) over-the-needle catheter inserted into the region percutaneously. Once fluid and gas stop draining, remove the catheter.

Orogastric Intubation

- Orogastric intubation can also be performed with either sedation or general anesthesia.
- To perform orogastric intubation, measure an orogastric tube from the tip of the nose to the last rib (Figure 38.3). Mark the tube, then lubricate it with sterile lubricant. Place a roll of 2-inch white tape (or mouth gag in an anesthetized animal) in the patient's mouth (Figure 38.4) and insert the tube through the roll of tape, to prevent the animal clamping down on the tube. Slowly insert the tube until the distal end of the tube enters the stomach. A rush of air and decompression of the abdominal distension should occur. Do not force the tube, as perforation of the esophagus or stomach can occur.
- An advantage of performing orogastric intubation with the patient under general anesthesia is that a cuffed endotracheal tube inserted into the trachea can help to prevent aspiration of gastric contents.
- Additionally, general anesthesia minimizes anxiety and patient discomfort associated with the procedure.
- For catastrophic cases that are dying before your eyes, or when immediate surgery is not possible, nasogastric intubation can be attempted.

Precautions/Interactions

- Nonsteroidal anti-inflammatory agents are not used in patients with GDV because of potential adverse effects to the GI tract.



■ **Figure 38.3** Measurement of an orogastric tube from the tip of the nose to the last rib prior to placement.



■ **Figure 38.4** Place the orogastric tube through a roll of 2-inch tape and secure tape around the muzzle to prevent the dog from biting through the tube.

- Corticosteroids have not been shown to reduce morbidity or mortality in the patient with GDV and may increase risk of GI ulceration and sepsis.

Surgical Considerations

- The stomach usually does not return to normal position without surgery, and the degree of gastric necrosis cannot be determined medically.
- The risk of reoccurrence of GDV without gastropexy is 54 to 76 percent.
- Emergency surgery is recommended to return the stomach to normal position, remove necrotic or ischemic gastric or splenic tissue, and pexy the stomach to the peritoneal wall.
- When possible, surgical preparation of the abdomen, ventral thorax, and inguinal area should be performed before anesthesia, to minimize anesthetic time.
- Also clip the lateral abdomen for possible gastrostomy or jejunostomy feeding tube placement.
- Prepare the inguinal area in case central femoral vascular access is required intraoperatively.

Anesthesia

- Perform rapid intravenous anesthetic induction to gain immediate control of the patient's airway.
 - Ketamine (5mg/kg) and midazolam/valium (0.25mg/kg) have few negative cardiovascular effects compared to barbiturates and propofol.
 - Fentanyl (10µg/kg IV) with diazepam (0.5–1.0mg/kg IV) can also be used to induce general anesthesia without causing any significant cardiovascular compromise.
 - The amount of pressure placed on the diaphragm by the dilated stomach will hinder effective chest expansion. Assisted ventilation is recommended regardless of spontaneous ventilatory efforts.
 - Epidural analgesia can reduce the amount of inhalant anesthetic required.

Intraoperative Monitoring

- ECG for detection of dysrhythmias.
- Blood pressure monitoring is important, especially when the stomach is decompressed completely, and the pressure on the central vein is released.
 - A sudden decrease in preload can produce acute hypotension.
 - Many anesthetic agents augment hypotension (iso-, sevo-flurane) or potentiate dysrhythmias (halothane).
- End-tidal CO₂ helps monitor for adequate ventilation.
- Pulse oximetry monitors trends of change in hemoglobin oxygen saturation.

Surgery

- Routine ventral abdominal midline incision from xyphoid to pubis to allow adequate exposure and evaluation of all abdominal organs.

- If there is significant hemorrhage, sterile laparotomy pads may be required for packing.
- Attempt to pass an orogastric tube. The surgeon can gently guide the tube into the stomach after palpation of the gastric antrum and cardia. Decompression will greatly facilitate derotation of the stomach.
- Derotate the stomach by using one hand to press the right side of the dilated stomach down and the other hand to grasp the pyloric region and gently pulled up ventrally (toward the surgeon) and to the right.
- If passage of the tube is not possible, and the stomach is not able to be derotated, a large-bore catheter stylet or needle can be used for centesis or attached directly to a suction apparatus for gas and fluid removal.
- If there is a large amount of food in the stomach, perform a gastrotomy to remove the ingesta.
- Control hemorrhage with packing or ligation following gastric derotation.
- Make note of any questionable gastric wall integrity, then explore the rest of the abdomen.
- Gastrectomy may not be required once blood flow is reestablished to the stomach.
- The spleen is often congested and may be displaced.
- Palpate the splenic arteries and examine the color of the splenic parenchyma to evaluate the spleen for thrombosis. Lack of palpable pulses in the vessels along the splenic hilus or dark-purple color means the spleen has lost its blood supply and a partial or complete splenectomy is warranted.
- Inspect the pancreas for loss of blood supply and edema.
- Inspect the remaining intestines for abnormalities.
- Finally, evaluate the hepatobiliary and genitourinary organs prior to re-evaluation of the stomach.
- Once the abdominal exploratory is completed, reinspect the stomach. Black or purple discoloration is often associated with gastric necrosis. Remove any black or dark purple regions with TA staples or resection.
- Any area that does not bleed bright red blood likely is nonviable and should be removed.
- Large invaginations of ischemic tissues are not recommended because of potential life-threatening hemorrhage that can occur when the tissues slough.
- In contrast to the serosa, when the mucosa is black, resection is not always necessary. The mucosa will regenerate if there is a healthy submucosa.
- Removal of compromised but viable tissue results in decreased hospital stay.
- Postoperative monitoring for intragastric hemorrhage is important.
- The type of pexy performed is completely dependent on the surgeon's preference and the time involved.
- If there has been any removal of gastric tissue, a tube gastrostomy, or combination tube gastrostomy and incisional gastropexy should be performed to permit continuous decompression and administration of microenteral nutrition.
- The incisional gastropexy is rapidly performed and provides reliable adhesion.

- It is not recommended to suture the gastric wall to the ventral midline abdominal incision, even in the critical GDV patient. Any future abdominal surgeries will be severely compromised by the adhesions formed.
- In the most critical patients with GDV, postoperative gastric decompression is recommended.
- Gastrostomy tube placement allows large volume decompression and removal of large clots that can occur with large resections.
- Nasogastric tubes are appropriate when gastric resection is not required. Nasogastric tubes are preferably placed intraoperatively with proper placement assured by palpation. Small volume infusion of electrolyte/glucose/glycine containing fluids feeds the gastric mucosal cells, which rely on intraluminal contents for nutrition.
- It is recommended that a jejunostomy or nasojejunosomy tube be placed if any significant gastric resection or pancreatic trauma has occurred. This permits the administration of postoperative enteral nutrition immediately during the postoperative recovery period.
- Copious saline lavage and suction of the abdomen are necessary. A routine three-layer closure is performed with placement of dressing over the incision site and ostomy tube sites.
- Any evidence of peritonitis warrants bacterial culture and susceptibility of the peritoneum and abdominal drainage.

Fluid Resuscitation

- Intravascular volume resuscitation and analgesia therapy are the keys to success, followed by gastric decompression.
- Initially (multiple) peripheral intravenous catheters are inserted, and intravenous crystalloid and colloid fluids are administered in conjunction with analgesic drugs.
- Bolus a balanced, buffered, isotonic solution rapidly in incremental dosages (20–30 ml/kg) in conjunction with incremental dosages of colloids (such as hydroxyethyl starch) until perfusion parameters (i.e., blood pressure, heart rate, capillary refill time) have normalized.
- Synthetic colloids preserve colloid osmotic pressure during fluid resuscitation.
- Hypertonic saline may benefit the patient that is rapidly deteriorating (4 ml/kg 7% solution) with synthetic colloid and buffered isotonic crystalloids.



COMMENTS

Client Education

- Following the recovery period, few restrictions are necessary.
- More frequent, less volume feedings may prevent a recurrence of gastric dilation.

Prevention/Avoidance

- More frequent, lower volume feedings may reduce the risk of GDV.
- Prophylactic gastropexy is being evaluated as a measure to prevent GDV in dogs at risk.
- Finally, not breeding dogs that have a first-degree relative or are a breed at risk for GDV potentially can reduce the overall incidence of GDV.

Possible Complications

- Gastric necrosis, gastric perforation, septic peritonitis, circulatory shock, and death are expected to occur in the untreated patient with GDV.

Expected Course and Prognosis

- Prognosis is good to excellent for dogs that receive immediate therapy and a surgical gastropexy procedure.
- Reported mortality rates are 10 to 54 percent for dogs with GDV. Risk factors significantly associated with death prior to suture removal are clinical signs > 6 hours prior to examination, combined splenectomy and partial gastrectomy, hypotension at any time, peritonitis, sepsis, disseminated intravascular coagulation, and presenting in a nonambulatory or comatose state.
- There is a reported reoccurrence rate of 4 to 6 percent of GDV in dogs following gastropexy. In addition, the gastropexy does not correct problems that cause delayed gastric emptying.

Synonyms

- Bloat

Abbreviations

- ACT: activated clotting time
- CO₂: carbon dioxide
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- GDV: gastric dilatation-volvulus
- GI: gastrointestinal
- IV: intravenously
- SIRS: systemic inflammatory response syndrome

Suggested Reading

- Beck, JJ, Staatz, AJ, Pelsue, DH, et al. Risk factors associated with short-term outcome and development of perioperative complications in dogs undergoing surgery because of gastric dilatation-volvulus: 166 cases (1992–2003) *J Am Vet Med Assoc* 2006;229(12):1934–1939.
- Brockman, DJ, and Holt, DE. Management of acute gastric dilatation-volvulus syndrome in dogs. *Comp Cont Ed* 2000;22:1025–1034.

- de Papp, E, Drobatz, KJ, and Hughes, D. Plasma lactate concentration as a predictor of gastric necrosis and survival among dogs with gastric dilatation-volvulus: 102 cases (1995–1998). *J Am Vet Med Assoc* 1999;215(1):49–52.
- Glickman, LT, Glickman, NW, Schellenberg, DB, et al. Incidence of and breed-related risk factors for gastric dilatation volvulus in dogs. *J Am Vet Med Assoc* 2000;216:40–44
- Glickman, LT, Glickman, NW, Schellenberg, DB, et al. Multiple risk factors for the gastric dilatation-volvulus syndrome in dogs: A practitioner/owner case control study. *J Am Anim Hosp Assoc* 1997;33:197–204.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Michelle J Waschak

Gastrointestinal Foreign Body/Obstruction



DEFINITION/OVERVIEW

- Gastrointestinal obstruction is a common condition encountered in small animal medicine. Obstruction is classically categorized as either mechanical or functional. Mechanical obstruction in the gastrointestinal tract is most often due to entrapped foreign material within the gastrointestinal lumen, but it can also be caused by intussusception, intestinal entrapment, torsion, mucosal or muscular hypertrophy, or neoplasia. Functional obstruction of the gastrointestinal tract, also referred to as ileus, most often results from inflammation or infection and is specifically addressed elsewhere.

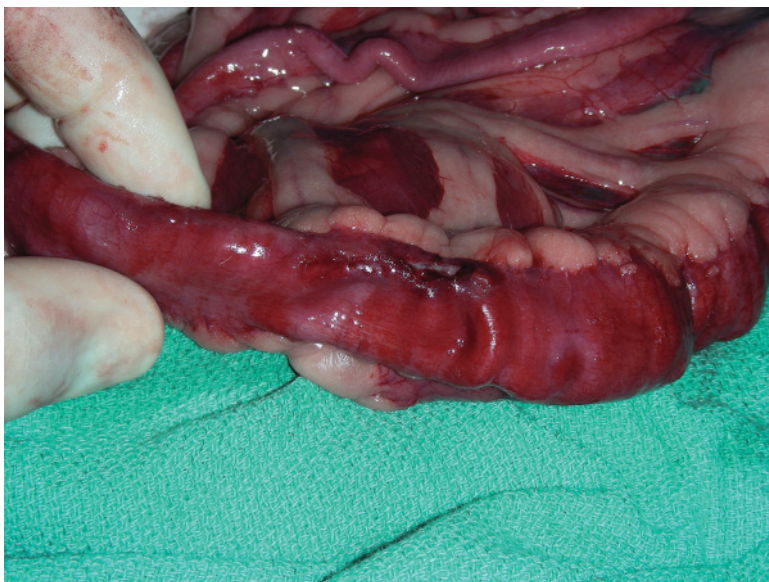


ETIOLOGY/PATHOPHYSIOLOGY

- Gastrointestinal mechanical obstruction may occur following indiscriminate ingestion of nonfood items. Frequently ingested items that may cause a focal obstruction include rocks, balls, toys, hair (trichobezars), corncobs, peach pits, plant material, and clothing items.
- Focal obstruction most commonly occurs at areas where the stomach and small intestine narrow (i.e., pylorus, caudal duodenal flexure, and ileocolic junction), although items may become lodged at any point along the gastrointestinal tract.
- Gastrointestinal obstruction with linear material is a unique situation most commonly associated with cats, but can occur in dogs as well. Foreign bodies such as string, thread, or cloth are ingested, become anchored typically at the base of the tongue or at the pylorus, and then cause a plicated obstruction as the intestinal tract attempts to move the piece of linear material caudally.

Systems Affected

- Gastrointestinal—Complete obstruction results in gas and fluid distension orad to the foreign body. Blood supply to the mucosa and submucosa is damaged, and full-thickness wall necrosis with perforation may occur at the obstruction site. With linear foreign body ingestion, peristalsis advances the material into the intestine, and as a result of the anchor, the intestine will gather around the foreign body. This plication of the intestines may cause a complete or, more often, partial obstruction.



■ **Figure 39.1** Intraoperative photograph of a dog with a linear foreign body showing perforation along the mesenteric border of the mid-jejunum.

Intestinal peristalsis continues against the fixed material and may lacerate the mucosa and cause perforations along the mesenteric border (Figure 39.1). The resulting peritonitis from gastrointestinal perforation secondary to foreign body ingestion is associated with poor wound healing and a high mortality rate.

- **Cardiovascular**—Complete mechanical gastrointestinal obstructions can lead to breakdown of the mucosal barrier, wall necrosis, or perforation and have a high likelihood of causing hypovolemic and septic shock.



SIGNALMENT/HISTORY

- There is no specific signalment associated with gastrointestinal foreign body obstruction, although there is a tendency for dogs and cats to be relatively young (<4 years).
- Cats more commonly ingest linear foreign material than dogs.
- Clinical signs associated with gastrointestinal obstruction are influenced by location, completeness, and duration of obstruction.
- Acute obstructions have a history most consistent with an acute abdomen: vomiting, bloody diarrhea, and abdominal pain (Figure 39.2).
- Complete high obstructions are associated with protracted vomiting, severe dehydration, electrolyte imbalance, and shock.
- Animals with chronic, partial, or low obstructions may have more vague clinical signs: inappetence, weight loss, occasional vomiting, and diarrhea.



■ **Figure 39.2** A 5-year-old female pug in the “praying” position demonstrating acute abdominal pain secondary to a small intestinal foreign body.

- Historical information may be valuable in aiding the diagnosis of gastrointestinal obstruction, as owners may report witnessing foreign material ingestion or know that objects from their home are missing.



CLINICAL FEATURES

- Physical examination may reveal a guarded painful abdomen. Animals will frequently display clinical signs consistent with dehydration: abnormal skin tent, dry mucous membranes, delayed CRT, and sunken globes.
- With linear foreign body obstruction, abdominal palpation is frequently painful and may reveal a large mass of bundled intestines ventrally. Careful oral examination may reveal the foreign material anchored around the base of the tongue.



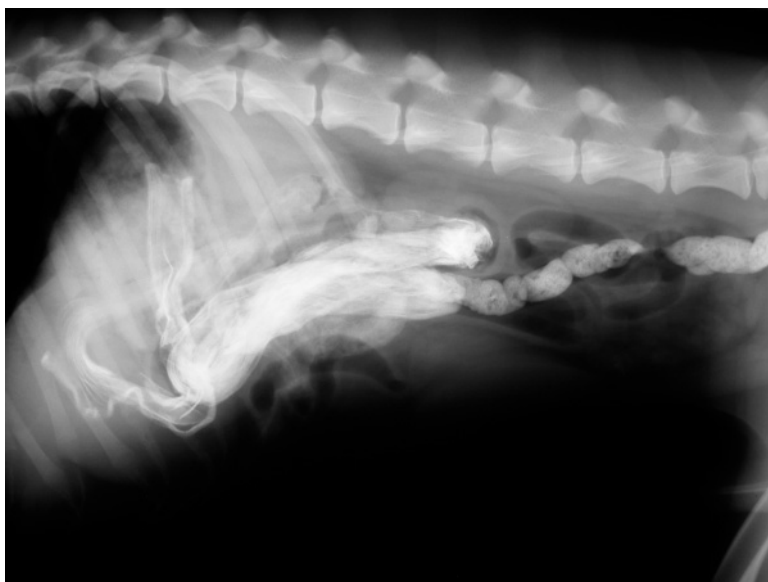
DIFFERENTIAL DIAGNOSIS

- Gastroenteritis
- Mesenteric torsion
- Intussusception
- Benign pyloric outflow obstruction
- Functional ileus
- Neoplasia
- Feline infectious peritonitis (cats)



DIAGNOSTICS

- Survey abdominal radiographs: Occasionally, radio-opaque foreign material causing obstruction can be visualized on abdominal radiographs. However, when the foreign body cannot be seen, mechanical obstruction may cause varying degrees of gastric and small intestinal dilation, depending on the location, degree, and duration of obstruction.
- For linear foreign body obstruction, the classic radiographic pattern of gathered intestines to the right of midline may be apparent, but intestinal loops are not usually abnormally dilated as the obstruction is incomplete. Small, eccentrically located luminal gas bubbles, tapered at one or both ends, are a more typical finding for linear foreign body obstruction.
- Additional imaging: If the diagnosis is still uncertain, survey radiographs may be repeated at a later time or other imaging techniques, such as upper gastrointestinal contrast studies or abdominal ultrasonography, may be performed.
- Ultrasound may detect foreign bodies by the distal acoustic shadowing and may also provide information regarding the integrity of the bowel wall and the presence of free abdominal fluid.
- Ultrasonographic appearance of a linear foreign body is described as a central hyper-echoic line with intestine plicated on either side.
- Gastrointestinal contrast studies can be performed when radiographic or ultrasonographic imaging is uncertain (Figure 39.3). However, barium contrast agents are



■ **Figure 39.3** A lateral abdominal radiograph following oral barium administration demonstrating linear foreign material in the stomach and small intestine.

contraindicated if perforation is suspected and iodinated contrast agents may exacerbate dehydration.

- Laboratory findings may demonstrate a wide range of electrolyte abnormalities, acid-base disturbances, anemia, hypoalbuminemia, stress or inflammatory leukograms, and evidence of dehydration.
- Obstruction at the pylorus or in the proximal duodenum may result in a classic hypochloremic, hypokalemic metabolic alkalosis that occurs from loss of electrolytes in protracted vomiting. However, these derangements can occur with distal obstruction as well.



THERAPEUTICS

- Gastrointestinal obstruction is considered a surgical emergency. Prior to surgery, the animal's hemodynamic and electrolyte status should be stabilized, although surgery should not be delayed unnecessarily. A complete and thorough abdominal exploratory is necessary to locate suspected obstructions. Conservative management of linear foreign bodies has been reported, but many cats managed medically ultimately require surgery.

Surgical Considerations

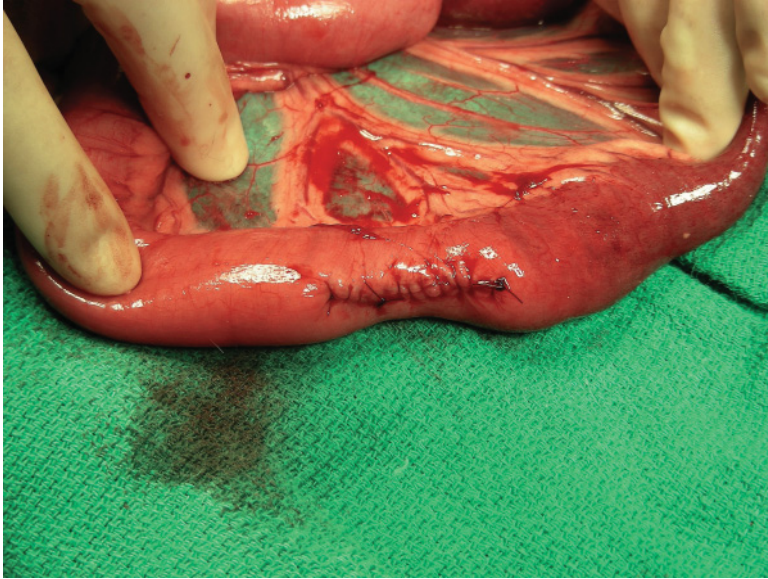
- Prophylactic antimicrobials are indicated as these surgeries are at a minimum classified as clean contaminated.
- Synthetic absorbable monofilament suture (3-0 to 4-0) with a swaged-on taper needle is the material of choice for most gastrointestinal surgery.
- There are numerous techniques described for closure of gastrointestinal incisions. Regardless of the suture pattern chosen, inclusion of the submucosal layer in the closure is vital. Full-thickness purchase of the tissue ensures that this holding layer is incorporated in the suture line.
- Gastrotomy is required for removal of gastric foreign bodies. The ventral body of the stomach is incised with a longitudinal incision between the lesser and greater curvature large enough to remove the foreign material. Specific options for gastrotomy closure include:
 - Two-layer continuous inverting pattern
 - Full-thickness simple continuous pattern followed by,
 - Partial-thickness (seromuscular) Lembert or Cushing pattern
 - Two-layer continuous inverting pattern
 - Simple continuous to close the mucosa and submucosa followed by,
 - Partial-thickness (seromuscular) Lembert or Cushing pattern
 - Single-layer full-thickness simple interrupted pattern
 - Single-layer full-thickness simple continuous pattern (Figure 39.4)
- For intestinal foreign bodies, subjective criteria are most often used to determine the viability of the tissue at the level of the obstruction and to decide whether simple



■ **Figure 39.4** Single-layer simple continuous closure of a gastrotomy incision following foreign body removal.

enterotomy or intestinal resection and anastomosis is indicated to address the problem. These parameters include: color, peristalsis, arterial pulsation, capillary (cut surface) bleeding, and tissue thickness. Multiple enterotomies are typically required for removal of linear foreign bodies. This allows for segmental removal of the material and minimizes the risk of iatrogenic perforation from too much traction.

- As with gastrotomy incisions, there are numerous ways to close simple enterotomies, however double-layer closures are typically avoided due to the potential for luminal compromise. Some options for simple enterotomy closure include:
 - Single-layer simple interrupted appositional pattern
 - Single-layer simple continuous appositional pattern (Figure 39.5)
- If intestinal resection and anastomosis are indicated, single-layer simple interrupted or modified simple continuous approximating patterns are also preferred. In a modified technique, two suture lines are used: one originating at the mesenteric border and the other originating at the antimesenteric border. A single-layer full-thickness continuous suture line is placed from the mesenteric knot to the stay suture at the antimesenteric knot with tissue purchases 2 mm from the wound edge and 2 to 3 mm apart. This is repeated on the other side from the antimesenteric knot to the mesenteric knot. There is no difference in reported rates of dehiscence between animals with simple continuous anastomotic closures and animals with simple interrupted closures.



■ **Figure 39.5** Single-layer simple continuous closure of an enterotomy incision following foreign body removal.



COMMENTS

Possible Complications

- Early recognition may prevent most major complications, however intestinal necrosis, perforation, dehiscence, peritonitis, and sepsis are all possible complications for gastrointestinal obstruction.

Expected Course and Prognosis

- The prognosis for animals with mechanical gastrointestinal obstruction is dependent on the location and completeness of the obstruction, as well as the duration of the obstruction.
- Linear foreign body obstruction carries a mortality rate of approximately 15 percent and is noted to be worse in dogs (22 percent) likely to the type of material causing the obstruction.
- If the gastrointestinal tract has been perforated and peritonitis is present, the prognosis is guarded. Perforated intestine from foreign material can carry a mortality rate as high as 50 percent.
- If proper surgical technique is not performed or if risk factors for poor intestinal healing are present (i.e., hypoalbuminemia, peritonitis, immunosuppression), dehiscence of gastrointestinal incisions may occur.
- Mortality associated with this scenario approaches 75 percent.

- Otherwise successful removal of foreign material and reestablishment of a patent gastrointestinal tract carries a good to excellent prognosis.

Abbreviations

- CRT: capillary refill time

Suggested Reading

Boag, AK, Coe, RJ, Martinez, TA, et al. Acid-base and electrolyte abnormalities in dogs with gastrointestinal foreign bodies. *J Vet Intern Med* 2005;19:816–821.

Evans, KL, Smeak, DD, and Biller, DS. Gastrointestinal linear foreign bodies in 32 dogs: A retrospective evaluation and feline comparison. *J Am Anim Hosp Assoc* 1994;30:445–450.

Tyrrell, D, and Beck, C. Survey of the use of radiography vs. ultrasonography in the investigation of gastrointestinal foreign bodies in small animals. *Vet Radiol Ultrasound* 2006;47:404–408.

Weisman, FL, Smeak, DD, Birchard, SJ, et al. Comparison of a continuous suture pattern with a simple interrupted pattern for enteric closure in dogs and cats: 83 cases (1991–1997). *J Am Vet Med Assoc* 1999;214:1507–1510

Wylie, KB, and Hosgood, G. Mortality and morbidity of small and large intestinal surgery in dogs and cats: 74 cases (1980–1992). *J Am Anim Hosp Assoc* 1994;30:469–474.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Brett M Feder

Glaucoma



DEFINITION/OVERVIEW

- The definition of glaucoma has changed considerably over time and is now considered to be a group of related diseases in which an elevation of IOP is a consistent feature.
- The increased IOP is detrimental to vision and ocular health.
- Primary glaucoma is a bilateral disease but most of the time one eye is affected before the other.



ETIOLOGY/PATHOPHYSIOLOGY

- Arises from decreased drainage of AH from the eye.
- Intraocular fluid production cannot be high enough to increase IOP unless drainage through the iridocorneal (drainage) angle is severely reduced.
- Primary glaucoma is due to an anatomical defect in the iridocorneal angle; either angle may be too narrow or may be covered with the remnant of an embryonic sheet of tissue.
 - It is a breed-related disease in dogs and cats; very common in dogs but rarely seen in cats.
- Secondary glaucoma is an increase in IOP due to another ocular condition such as uveitis, neoplasia or lens luxation.
 - Secondary glaucoma is the most common type seen in cats and is also common in dogs.
 - The most common cause of secondary glaucoma in dogs is lens-induced uveitis secondary to cataract formation.

Systems Affected

- Glaucoma only affects the ophthalmic system.



SIGNALMENT/HISTORY

- Many breeds of dogs are affected with primary glaucoma (see Table 40.1).
- In cats breed-predisposition for glaucoma has been reported in Siamese, Persian, Burmese, and European shorthair.

TABLE 40.1 Breeds of dogs reported to have primary glaucoma (adapted from Gelatt KN Ed. *Veterinary Ophthalmology*, 2008).

| | | |
|----------------------|--------------------------|-----------------------------|
| Akita | Dandie Dinmont terrier | Norwich terrier |
| Alaskan malamute | English cocker spaniel | Poodle |
| Basset hound | English springer spaniel | Samoyed |
| Beagle | German shepherd | Scottish terrier |
| Border collie | Giant schnauzer | Sealyham terrier |
| Boston terrier | Greyhound | Shih tzu |
| Bouvier des Flanders | Irish setter | Siberian husky |
| Brittany spaniel | Italian greyhound | Smooth fox terrier |
| Cairn terrier | Lakeland terrier | Tibetan terrier |
| Cardigan Welsh Corgi | Maltese | Welsh springer spaniel |
| Chihuahua | Miniature pinscher | West Highland white terrier |
| Dachshund | Miniature schnauzer | Wirehaired fox terrier |
| Dalmatian | Norfolk terrier | |

- Sex predilection for primary glaucoma in dogs varies by decade but in some breeds (e.g. American and English cocker spaniels, basset hound, Cairn terrier, Jack Russell terrier, Norwegian elkhound, Samoyed and Siberian husky) females were more often affected.
- No sex predilection has been noted in cats.
- There is no sex predilection for secondary glaucoma in dogs or cats except in the cases caused by primary diseases with given sex predilections (e.g., uveodermatologic syndrome).
- Age of onset of primary glaucoma in dogs varies considerably by breed but ranges from 4 to 10 years.
- No age of onset for glaucoma has been reported in cats.

Historical Findings

- Squinting and epiphora from the affected eye.
- Red eye—due to episcleral congestion (Figure 40.1)
- Dogs may be more quiet and depressed than usual. A red or cloudy eye may be noticed.
- Cats often have no historical findings.



CLINICAL FEATURES

Dogs

- Clinical signs vary according to stage and type of glaucoma.
- Early primary glaucoma is insidious and clinical signs may be very subtle and can be missed unless IOPs are obtained.



■ **Figure 40.1** Red sclera with corneal cloudiness consistent with glaucoma.

- The signs include slight mydriasis, mild corneal edema, variable episcleral hyperemia and mild elevations in IOP (25–30 mm Hg).
- Signs of moderately advanced glaucoma include pronounced mydriasis, episcleral hyperemia, distinct corneal edema and variable vision loss. IOP usually ranges from 30 to 40 mm Hg.
- Advanced glaucoma is characterized by persistent mydriasis, blindness, corneal edema with striae, and often lens luxation, buphthalmia (ocular enlargement) and optic disk changes. Intraocular pressure may be very high (40–60 mm Hg) (Figure 40.2).
- Signs of secondary glaucoma are those of primary glaucoma with the addition of the signs of the primary cause (e.g., uveitis, intraocular neoplasm, lens luxation).

Cats

- Clinical signs are often more subtle than in dogs and therefore may be easily overlooked.
 - Frequently clinical signs have been present for an extended period and blindness and buphthalmia are present.
- Mydriasis is the most consistent finding in early glaucoma.
- Episcleral hyperemia and conspicuous corneal edema (which occur in dogs) usually do not develop in cats.
- Elevated IOP is present.



■ **Figure 40.2** End-stage glaucoma in a Siberian husky. Note the cloudy cornea and buphthalmic appearance to the dog's left eye.



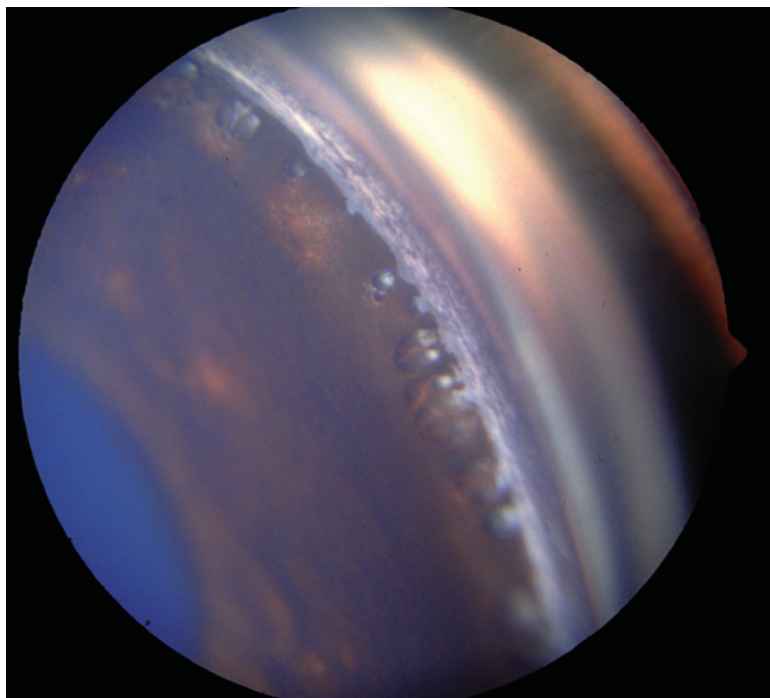
DIFFERENTIAL DIAGNOSIS

- Conjunctivitis—redness limited to conjunctival hyperemia, less severe discomfort which is alleviated by topical anesthetic
- No corneal edema or striae.
- Uveitis—aqueous flare is present, IOP is low, pupil is usually miotic.
- Ulcerative keratitis—corneal fluorescence staining is positive, corneal edema is localized to one or several areas, and discomfort is alleviated by topical anesthetic.
- Corneal endothelial dystrophy—diffuse corneal edema but not painful and IOP is normal.



DIAGNOSTICS

- Tonometry—elevated IOP. May range from 25 to 75+ mm Hg depending on stage and severity. This is the definitive test.
- Gonioscopy—allows for direct visualization of the iridocorneal angle (Figure 40.3).
 - Facilitates differentiating primary vs. secondary glaucoma and prognosis of the unaffected eye.
- Ophthalmoscopy—to evaluate the optic disk for cupping.
 - Allows for prognosis. A cupped optic disk indicates a poor prognosis for vision.



■ **Figure 40.3** Drainage angle in a dog with glaucoma.



THERAPEUTICS

- Treatment modality is initially based on the absence or presence of vision on presentation, willingness of the owner to treat the patient, cost of therapy, and patient temperament.
- Objective of therapy in sighted eyes is to lower the IOP as rapidly as possible.
- This may preserve vision and will alleviate pain.

Medical Therapy for Primary Glaucoma

Initial Medical Intraocular Pressure Control (Emergency)

- Osmotic diuretics
 - Mannitol: intravenous; give 1 to 2 g/kg over 20-minute period; onset 30 to 60 minutes; duration 5 to 6 hours; can be repeated. Contraindicated if concurrent congestive heart failure, renal disease, systemic hypertension, or dehydration are present. Withhold water or intravenous fluids for 2 to 4 hours.
 - Glycerine (Glycerine USP 75%, Osmoglyn 50%): oral; give 1 to 2 ml/kg; not as effective as mannitol; onset 10 to 30 minutes; duration 4 to 5 hours; can be

repeated; contraindicated if concurrent congestive heart failure, renal disease, systemic hypertension, or dehydration are present. Care should be taken to give slowly so dog does not inhale it.

- Will not work well if concurrent uveitis.
- Prostaglandins: topical
 - Latanoprost, travoprost, or bimatoprost
 - topical; apply 1 drop every 12 hours.
 - Cause profound miosis
 - Ineffective in cats
- Miotics: topical
 - Parasympathomimetics
 - Pilocarpine (1 or 2%): apply two to three times daily; may be irritating.
 - Demecarium bromide (0.125% or 0.250%): apply once daily; contraindicated in cats.
- Adrenergics: topical
 - β -blockers
 - Timolol (0.5%), betaxolol, levobunolol: apply 1 drop every 8 to 12 hours depending on severity.
 - Controversial as to effectiveness in dogs.
 - Few side effects.
- Neuroprotective drugs
 - Calcium channel blockers; oral
 - Amlodipine (0.625 mg once daily); may help protect retinal ganglion cells.

Short-Term Intraocular Pressure Control

- Prostaglandins: use as previously described; good for control; disadvantage is expense.
- Miotics (use as previously described); use with care if anterior uveitis is present as synechiae can occur or if there is a luxated lens as pupil can constrict around lens and cause exacerbation of glaucoma.
- Adrenergics (β -blockers): use as previously described.
- Neuroprotective drugs: use as previously described.
- Carbonic anhydrase inhibitors
 - Topical
 - Dorzolamide, brinzolamide: apply every 8 hours.
 - Oral
 - Acetazolamide: 10 mg/kg twice a day, methazolamide: 5 mg/kg twice a day, or dichlorphenamide: 2.5 mg/kg two or three times a day
 - CAIs are useful for short- or long-term therapy; CAIs are kaluretic agents and therefore potassium supplementation is recommended if CAIs are used long term.

Long-Term Intraocular Pressure Control

- Miotics, prostaglandins, adrenergics, CAIs and neuroprotective drugs may be used long term in the dosages used above.
- Often surgical therapy.

Surgical Therapy for Primary Glaucoma

- Patient selection is important; must have sighted eye; chronically increasing IOP despite medical therapy indicates good candidates.
- Early surgical intervention is recommended; best potential to save vision
- Two types are available; can use both approaches for some patients.
 - Surgeries that construct alternate drainage methods: anterior chamber shunts (gonioimplants), cyclodialysis; variable success rate long term; many complications; should be done by ophthalmologist
 - Surgeries that decrease AH formation: cyclocryotherapy, cyclodiathermy, transscleral cyclophotocoagulation (LASER); these destroy part of the ciliary body which produces AH-; cyclocryotherapy can be done in a general veterinary practice.

Treatment of End-Stage Primary Glaucoma

- Used when the eye is blind
- Objectives of therapy are to provide a pain free, cosmetically acceptable situation.
- Available procedures
 - Enucleation—removes the entire problem; high success rate
 - Evisceration—removal of the contents of the eye with intrascleral prosthesis placement; more cosmetically acceptable for some clients; the eye is still in place and is subject to trauma and ulcers.
 - Pharmacologic ablation—injection of gentamycin into the eye to kill the ciliary body epithelium and eliminate aqueous humor production; not as reliable and second injection is required in 50 percent of the patients; eye is still in place and is subject to trauma and ulcers.

Treatment of Secondary Glaucoma

- Objectives of therapy: treat the primary cause as well as lower IOP; treat uveitis (including cataract-associated inflammation) with topical antiinflammatories (see section on uveitis); surgical removal is indicated in lens luxation.
- Treatment to lower IOP is as listed previously.

Precautions/Interactions

- If uveitis is present osmotic diuretics are ineffective and could worsen the glaucoma; miotics and prostaglandins (that induce miosis) are not indicated in cases of lens luxation; osmotics should not be used if there has been head trauma or if there is dehydration, congestive heart failure, hypertension or renal disease.

Diet

- No changes in patient's diet are necessary; dogs that need chronic CAI therapy should have potassium supplementation.



COMMENTS

Client Education

- It is important to inform clients that primary glaucoma can only be controlled, not cured and that in almost all of cases, vision will be lost eventually.
- Medications must be given as directed or IOP can elevate quickly and vision can be rapidly lost.
- Monitor for squinting, redness, and cloudy cornea.

Patient Monitoring

- After an acute glaucoma episode the IOP should be checked in 24 hours and if low, again in 5 to 7 days. Frequency of subsequent rechecks is based on what is necessary to maintain IOPs within a normal range.

Prevention/Avoidance

- There is no way to prevent primary glaucoma because one eye often becomes affected before the other, the unaffected eye should be treated with an anti-glaucoma drug (e.g., demercarium bromide: apply 1 drop every 24 hours indefinitely); this may help delay the onset of glaucoma.
- Discourage breeding (neuter) of affected dogs.

Possible Complications

- Few systemic complications; vision loss almost always occurs.

Expected Course and Prognosis

- Primary glaucoma will almost always progress to blindness; with therapy vision can be retained for variable periods of time and pain can be eliminated.

Abbreviations

- AH: aqueous humor
- CAI: carbonic anhydrase inhibitor
- IOP: intraocular pressure

Suggested Reading

- Abrams, KL. Medical and surgical management of the glaucoma patient. *Clin Tech Small Animal Practice* 2001;16:71.
- Blocker, T, and van der Woerd, A. The feline glaucomas: 82 cases (1995–1999). *Veterinary Ophthalmology* 2001;4:81.

- Gelatt, KN, Brooks, DE, and Kallberg, ME. The canine glaucomas. In: Gelatt KN, ed. *Veterinary Ophthalmology*, 4th ed., pp. 753–811, Ames, Iowa: Blackwell Publishing, 2007.
- Martin, CL. Glaucoma. In: *Ophthalmic Disease in Veterinary Medicine*, pp. 337–364. London: Manson Publishing, 2005.
- Miller, PE. The glaucomas. In: Maggs, DJ, Miller, PE, and Ofri, R, eds. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed., pp. 230–257. St. Louis: Saunders, Elsevier, 2008.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: J. Phillip Pickett

Head Trauma/Traumatic Brain Injury (TBI)



DEFINITION/OVERVIEW

- TBI describes a spectrum of injuries to the brain after blunt or penetrating trauma to the head.



ETIOLOGY/PATHOPHYSIOLOGY

- Primary brain injury: The injury that occurs to the brain at the time of trauma. This includes shearing injury, lacerations from depressed skull fractures or penetrating wounds, and hemorrhage. There is little that can be done medically to reverse primary brain injury.
- Secondary brain injury: The injury that occurs to the brain as a result of the primary injury. Most medical therapy in the TBI animal is used to limit secondary injury by maintaining oxygen delivery to the brain.

Systems Affected

- Nervous—Direct trauma to the brain or decreased cerebral oxygen delivery can alter neurological function after trauma.
- Ophthalmic—TBI often occurs coincident with ocular injury, or it may result altered pupil size (Figure 41.1), response to light, ocular position, or movement in the absence of ocular injuries.
- Cardiovascular—Trauma to the brain can affect the vasomotor center of the brain, resulting in cardiac arrhythmias or altered vascular tone. In addition, when intracranial pressure increases, peripheral vasoconstriction resulting in hypertension and reflex bradycardia may be noted.
- Respiratory—Trauma to the brain can affect the respiratory center resulting in an altered respiratory pattern or a decreased ventilatory drive.
- Musculoskeletal—Skull and jaw fractures are often seen in animals with TBI (Figures 41.2 and 41.3).
- Endocrine/Metabolic—Following TBI, animals may develop central diabetes insipidus.



■ **Figure 41.1** Anisocoria in a cat with head trauma following a motor vehicle accident.



■ **Figure 41.2** Avulsion of the nose from the maxilla in a puppy with head trauma caused by a larger dog.



■ **Figure 41.3** Herniation of the brain through a skull fracture in a puppy with head trauma secondary to an altercation with a larger dog.



SIGNALMENT/HISTORY

Risk Factors/Causes

- There are no specific breed, sex, or age predilections.
- Pediatric and juvenile cats and dogs are frequently presented for TBIs. One study reported that the average age of cats with TBI trauma at 2.5 months and dogs at 2 years.
- Animals allowed to roam free may be more likely to sustain trauma.

Historical Findings

- Blunt trauma is most commonly reported to occur prior to onset of signs of TBI: often a result of vehicular trauma, falling from a height, intentional or inadvertent injury from humans or other animals, or crushing injury as occurs when an object falls onto the animal.
- Penetrating trauma is less common but causes significant TBI; may occur secondary to animal bite wounds, projectile injury (e.g., gunshots, arrows), or impalement onto objects.
- Owners may report decreased level or loss of consciousness, seizures, or vomiting that occurs either immediately following or slowly progressing after a traumatic injury.



CLINICAL FEATURES

- Altered level of consciousness
- Altered pupil size and pupillary light reflexes
- Postures associated with intracranial hypertension such as decerebrate (i.e., extended head and neck, extensor rigidity of front limbs, decreased level of consciousness) and decerebellate rigidity (i.e., extended front limbs, flexed hindlimbs, animal remains aware).
- *Note:* TBI often occurs concurrent with other systemic traumatic injuries; this is particularly true in animals that sustain blunt trauma.



DIFFERENTIAL DIAGNOSIS

- Usually TBI is obvious, particularly when a traumatic event was witnessed. However, when a traumatic event was either not witnessed or known, a diagnosis of head trauma may be more difficult. The presence of abrasions, lacerations, bruises, road dirt, fractures, and fraying of the claws should alert one to the possibility of trauma. Otherwise, the following differentials should be considered:
 - Intracranial diseases
 - Inflammatory CNS disease (i.e., GME, pug encephalitis, etc.)
 - Infectious CNS disease (i.e., canine distemper virus, FIP, toxoplasmosis, Cryptococcus, etc.)
 - Neoplasia (primary brain tumors or metastatic brain tumors)
 - Postictal phase following a seizure
 - Vascular (i.e., infarct, ischemia, hemorrhage)
 - Animals with primary intracranial disorders may exhibit symmetrical or asymmetrical clinical signs. The history in these animals may include lack of trauma and a more gradual onset and progression of clinical signs. Cerebral spinal fluid analysis, serologic testing, and CT or MRI are used to establish a diagnosis.
 - Extracranial diseases
 - Severe hypoperfusion secondary to hypovolemia: the presence of tachycardia, hypotension, reduced pulse quality, pallor of mucous membranes, and prolongation of capillary refill time will help to discern if shock is contributing to altered mentation.
 - Hypoglycemia: blood glucose concentration <60 mg/dL; many animals with TBI are hyperglycemic.
 - Severe hypothermia
 - Hepatic encephalopathy: the presence of elevated blood ammonia concentrations, bile acids or evidence of impaired liver function on a chemistry profile
 - Thiamine deficiency: more common in cats on a fish-only diet
 - Lead toxicity: history of exposure, recent home renovations, nucleated red blood cells, blood lead levels



DIAGNOSTICS

- Skull radiographs are rarely useful, but they may detect depressed skull fractures. CT is the advancing imaging tool of choice following acute TBI; it is superior for detection of acute hemorrhage, edema, and fractures compared to MRI.



THERAPEUTICS

- Treatment of TBI should focus on optimizing cerebral oxygen delivery by improving systemic oxygenation, ventilation, and perfusion as well as decreasing ICP.
- Maintenance of blood pressure by fluid resuscitation.
- Maintenance of oxygenation ($\text{SpO}_2 > 96\%$, $\text{PaO}_2 > 80 \text{ mm Hg}$) and ventilation ($\text{PCO}_2 < 45 \text{ mm Hg}$).
- Decrease ICP (mannitol, hypertonic saline, elevate head and neck 15–30 degrees, avoid jugular compression).
- Decrease cerebral metabolic rate (avoid fever, vocalization/paddling, seizures).

Drug(s) of Choice

- Hypertonic saline (7.0–7.8%): 3 to 5 ml/kg (dogs) or 2 to 3 ml/kg (cats) IV every 5 to 15 minutes. Can be combined with artificial colloids to prolong duration of action. Used to rapidly improve systemic perfusion and decrease ICP.
- Mannitol: 0.5 to 1.5 g/kg as an infusion over 15 to 20 minutes. Should be avoided in hypovolemic patients until systemic perfusion has been restored.
- Pure agonist opioid agents should be used for analgesia and the dose titrated to clinical effect (i.e., hydromorphone 0.05–0.2 mg/kg IV or IM every 4–6 hours).

Precautions/Interactions

- Corticosteroids are *not* indicated in the management of animals with TBI.
- The following drugs may worsen secondary brain injury:
 - Ketamine may increase cerebral metabolic rate and increase the demand for oxygen by the injured brain.
 - Acepromazine may cause vasodilation and hypotension, which will decrease cerebral perfusion.
 - α_2 antagonists cause bradycardia which could decrease cerebral perfusion and hypoventilation, which may increase ICP.
- Dextrose should only be supplemented to those animals who demonstrate a glucose concentration $< 80 \text{ mg/dL}$. It should not automatically be supplemented to pediatric animals.
- Hypotonic crystalloids (i.e., 0.45% NaCl or 5% dextrose in water) should not be used for intravenous fluid therapy because this could increase cerebral edema.

- The use of analgesics should *not* be avoided because of a concern that they may alter the animal's neurological status. Pain should be treated appropriately.
- Partial opioid agonist/antagonists, such as butorphanol, should be avoided as they are difficult to reverse with naloxone should respiratory depression occur.

Diet

- Nutrition should be instituted with 72 hours of TBI because head injury induces a hypercatabolic state.
- Force feeding should not be used. Placement of an esophagostomy or gastrostomy tube will facilitate early institution of enteral nutrition in animals with altered levels of consciousness.

Surgical Considerations

- Depressed skull fractures
- Epidural or subdural hematomas



COMMENTS

Client Education

- Owners should be aware that pets surviving severe head trauma may have residual neurologic deficits that may take months to resolve or may never fully resolve.

Patient Monitoring

- Modified Glasgow Coma Scale: serial can be used to assess severity of injury and response to therapy.
- Blood pressure: maintain systolic pressure >90 mm Hg.
- Oxygenation: maintain SpO₂ > 96% or PaO₂ > 80 mm Hg.

Expected Course and Prognosis

- Prognosis is dependent upon response to therapy. Minimal neurological deficits, lack of progression of clinical signs over 12 to 24 hours or improvement with therapy are good prognostic indicators. Poor prognostic indicators include an altered level of consciousness, which is either static or deteriorates during treatment, progressive pupillary dilation, or loss of pupillary light response, and loss of physiologic nystagmus.

Abbreviations

- CNS: central nervous system
- CT: computed tomography
- FIP: feline infectious peritonitis

- GME: granulomatous meningoencephalitis
- ICP: intracranial pressure
- IM: intramuscularly
- IV: intravenously
- MRI: magnetic resonance imaging
- NaCl: sodium chloride
- PaO₂: partial pressure of oxygen in blood
- PCO₂: partial pressure of carbon dioxide in blood
- SpO₂: pulse oximeter oxygen saturation
- TBI: traumatic brain injury

Suggested Reading

Brain Trauma Foundation. Guidelines for the management of severe head injury. *J Neurotrauma* 2007;24:S1–S106.

Syring, RS. Assessment and treatment of CNS abnormalities in the emergent patient. *Vet Clin North Amer Small Anim Pract* 2005;35:343–358.

Syring, RS. Traumatic brain injury. In: Ettinger, SJ, Feldman, ED, eds. *Textbook of Veterinary Internal Medicine*, 6th ed., pp.409–412. Philadelphia: W. B. Saunders.

Author: Rebecca S. Syring

Heat Stroke and Heat-Induced Illness



DEFINITION/OVERVIEW

- Hyperthermia can be categorized as pyrogenic hyperthermia (pyrexia or fever) or nonpyrogenic hyperthermia.
- Heat stroke, or heat-induced illness, occurs when heat dissipating mechanisms are exceeded by heat gain, and the body cannot accommodate excessive heat. When left untreated and severe, heat stroke often leads to multiorgan dysfunction or failure, and could lead to death.
- Heat stroke, or nonpyrogenic hyperthermia, is most commonly observed during warm and humid months, although can occur at any time of year, depending on the predisposing cause and patient risk factors.
- When body temperature exceeds 106°F (41°C) without signs of inflammation, non-pyrogenic hyperthermia exists (Figure 42.1).



■ **Figure 42.1** Thermometer demonstrating rectal temperature too high to register (>109°F) in a dog with heat stroke.

- Malignant hyperthermia is an uncommon condition that causes nonpyrogenic hyperthermia that can occur due to inhalation of anesthetic agents and is familial in some breeds of dog, including the Labrador retriever.
- Other causes of hyperthermia and heat-induced illness include excessive exercise, thyrotoxicosis, hypothalamic lesions/dysfunction, and status epilepticus.



ETIOLOGY/PATHOPHYSIOLOGY

- Under normal circumstances, body temperature is regulated by a balance of heat gain and compensatory mechanism for heat loss or dissipation. Nonpyrogenic hyperthermia, or heat stroke, occurs when heat dissipating mechanisms become overwhelmed, and the core body temperature rises.
- Normal heat dissipation mechanisms in small animals include evaporative loss through the respiratory tract during panting and hypersalivation, convective and radiation losses from peripheral vasodilation, and seeking cooler locations. Warm blood at the periphery loses some heat as the body lies on a cool surface, for example.
- Nonexertional heatstroke occurs when an animal is enclosed in a warm environment and cannot escape.
- Exertional heatstroke occurs when an animal exercises in warm environment and has not been acclimated or allowed to rest. Strenuous exercise in warm and humid environments can allow the normal heat dissipating mechanisms to be overwhelmed, and core body temperature rises above the hypothalamic set point. Vascular endothelial injury, sludging of blood flow, vasodilation, and hypotension contribute to decreased vital organ perfusion and tissue ischemia. Without treatment, damage to the GI tract, liver, kidneys, heart, and central nervous tissue occurs, and can lead to SIRS, DIC, and MODS. The most extreme cases are often fatal.

Systems Affected

- Neurologic—Direct thermal injury and oxidative injury to neurons cause cellular swelling, tissue hypoxia, and central nervous system dysfunction.
- GI—decreased mesenteric blood flow, decreased perfusion, bacterial translocation from GI tract, sloughing of basement membrane, and thermal damage to enterocytes
- Hepatic—decreased splanchnic/portal blood flow, direct thermal injury to hepatocytes, hepatocellular ischemia and necrosis, cholestasis, decreased glycogenolysis, and gluconeogenesis
- Renal—direct thermal injury to nephrons/renal tubular cells and glomerular basement membrane, hypoxic and oxidative damage, renal ischemia secondary to decreased perfusion/hypotension, myoglobinuria, and renal failure
- Cardiovascular—direct thermal injury to cardiac myocytes, tissue ischemia, and dysrhythmias
- Respiratory—thermal injury to pulmonary endothelium, increased pulmonary vascular resistance, alveolar edema and hemorrhage, and ARDS in severe cases
- Musculoskeletal—thermal damage to myocytes and rhabdomyolysis

- Hemic/lymphatic/immune—hemoconcentration, thrombocytopenia, direct thermal injury to vascular endothelium, venous stasis, and exposure of tissue factor leads to Virchow's triad and consumption of platelets and clotting factors, DIC.
- Acid-base—respiratory alkalosis, metabolic acidosis, and lactic acidosis

Geographic Distribution

- Can occur in any warm-weather climate, although also can occur when animals are locked in cars with the heater running on cold days
- More common in warm and humid environments



SIGNALMENT/HISTORY

Species

- Primarily dogs, but can occur in cats

Breed Predisposition

- Brachycephalic breeds (i.e., English bulldog, pug, Shar Pei, Pekingese, bull terrier), Belgian Malinois, breeds predisposed to laryngeal paralysis or tracheal collapse (golden and Labrador retrievers; Yorkshire terriers), boxer, Rottweiler, St. Bernard, Weimaraner, Australian shepherds

Mean Age and Range

- All ages, but often very young and older animals
- Older dogs with pre-existing disease
- Younger dogs with over-enthusiastic energy levels

Historical Findings

- Identifiable underlying cause (i.e., hot day, locked in automobile or other confined area without adequate ventilation, grooming accident associated with heaters on drying cages, excessive exercise, limited access to water or shade)
- Predisposing underlying diseases (laryngeal paralysis, brachycephalic airway syndrome, cardiovascular disease, tracheal collapse, neuromuscular disease, upper airway mass lesion or obstruction, previous history of heat-induced illness)

Physical Examination Findings

- Panting
- Tachy or dry mucous membranes
- Hyperemic mucous membranes
- Markedly rapid or very delayed capillary refill time
- Neurologic abnormalities—altered level of consciousness, ataxia, cortical blindness, involuntary paddling, tremors, seizures, obtundation, coma

- Petechial hemorrhages
- Tachycardia
- Weak femoral pulses
- Pulse deficits
- Cardiac dysrhythmias
- Bloody diarrhea or melena, sometimes with GI mucosal sloughing
- Dark urine

Risk Factors/Causes

- Excessive environmental temperatures or humidity; note, it can occur in lower temperatures and in as little as 30 minutes in animals not acclimated to exercise.
- Unventilated areas (e.g., hot room, locked in an automobile, or a dryer cage at groomers)
- Exercise
- Toxicosis (strychnine, metaldehyde, mycotoxin, mushroom) that lead to seizures
- Anesthesia (malignant hyperthermia)
- Previous history of heat-related illness
- Age extremes
- Obesity
- Poor acclimatization to heat
- Hyperthyroidism
- Cardiopulmonary disease
- Brachycephalic airway disease
- Tracheal collapse
- Upper airway obstruction
- Thick haircoat
- Dehydration
- History of seizures



DIAGNOSTICS

- Differentiating causes

Complete Blood Count/Chemistry/Urinalysis

- May be helpful in identifying an underlying disease process
- May be beneficial in identifying sequelae in hyperthermia
- CBC abnormalities may include a stress leukogram, leukopenia or transient leukocytosis, hemoconcentration or possibly anemia, nucleated red blood cells, thrombocytopenia.
- Biochemical profile may show azotemia, hyperbilirubinuria, elevated hepatocellular and cholestatic enzymes (i.e., ALT, AST, CK, Alk Phos), hypernatremia, hyperchloremia, hyperglycemia or hypoglycemia, hyperphosphatemia, hyper- or hypokalemia, hyperbilirubinemia, or hypoproteinemia/hypoalbuminemia.

- Urinalysis may include hyposthenuria, proteinuria, cylindruria, renal tubular casts, hemoglobinuria, myoglobinuria, glucosuria; evaluate USG for renal concentrating ability prior to administration of intravenous fluids, when possible.

Other Laboratory Tests

- Blood gas analysis may show mixed acid-base disorder, respiratory alkalosis, or metabolic acidosis.
- Coagulation profiles may indicate prolonged PT, aPTT; FDPs or D-dimers may be positive. DIC may be present if PT and PTT are prolonged, and if FDPs or D-dimers are positive. Antithrombin levels may be decreased. Platelet count is usually decreased, or trends toward thrombocytopenia.
- Electrolytes—hyperkalemia (mild), hypophosphatemia, hypocalcemia
- Lactate—elevated

Diagnostic Procedures

- Minimum data base—PCV/TS, peripheral blood smear evaluation, platelet estimate, blood glucose, BUN
- CBC
- Chemistry
- Urinalysis
- Lactate
- aPTT and PT
- \pm D-dimers

Imaging

- Thoracic radiographs may help identify underlying cardiopulmonary disease or predisposing causes of heat stroke.
- Abdominal radiographs and/or ultrasound may help identify underlying disease process. May observe fluid-filled loops of bowel.
- CT or MRI may help identify hypothalamic or other mass lesion.



THERAPEUTICS

- The key to treatment is early recognition and immediate correction of hyperthermia.
- ABCs of emergency: airway, breathing, and circulation: establish an airway if airway obstruction, clear mucus or vomitus from oropharynx and trachea, if necessary; intubate if airway obstruction; need to perform emergency tracheostomy or tracheal oxygen in most severe cases of airway obstruction; if heat stroke has occurred secondary to seizures or airway obstruction, monitor patient carefully for development of noncardiogenic pulmonary edema.
- Institute cooling measures: Place towels soaked in room-temperature water over patient and place a fan over the patient (Figure 42.2). This will allow convective and



■ **Figure 42.2** Dog with laryngeal paralysis that succumbed to heat stroke while playing ball on a very hot summer day. Note the cool towels placed over the dog to allow convective cooling to occur.

radiant cooling measures. Do *not* immerse in cold or ice water or ice packs because this can promote peripheral vasoconstriction. Peripheral vasoconstriction is one of the primary means of heat dissipation. By removing the compensatory mechanism, core body temperature can continue to rise and cause worsening of clinical signs. As a general rule, patients should be cooled to a temperature of 39.4°C (103°F), then external cooling measures should be stopped, to avoid overcooling.

- Continuous temperature monitoring; hospitalization is required until temperature has normalized and is stable even in the least critical patients.
- Intensive care monitoring is common and necessary in most cases.
- Treat complications such as DIC, noncardiogenic pulmonary edema, ARDS, cerebral edema, seizures, renal failure, and MODS.
- Treat underlying disease and/or correct predisposing factors.
- Isotonic crystalloid fluid therapy based on degree of dehydration and fluid loss (GI tract)
- Synthetic colloids (i.e., hydroxyethyl starch) in incremental boluses (5 ml/kg) or 20 to 30 ml/kg per day may be required to aid in the treatment of hypotension or hypoproteinemia.
- Provide supplemental oxygen by nasal or nasopharyngeal oxygen catheter, tracheal oxygen, oxygen cage, or oxygen mask (50–150 ml/kg per minute).
- Mechanical ventilation may be required, depending on the degree of cerebral edema, hypoventilation, pulmonary disease, or airway obstruction.
- Antibiotics
- Treat hypoglycemia if present.
- Gastroprotectants

- Correction of acid-base and electrolyte abnormalities
- Treat dysrhythmias
- Treat hypotension

Drug(s) of Choice

- Antibiotics—broad-spectrum antibiotics to cover both gram-negative and gram-positive infections; choices include ampicillin (22 mg/kg IV every 6–8 hours) with enrofloxacin (10 mg/kg IV every 24 hours in dogs, 5 mg/kg IV every 24 hours in cats), cefazolin (22 mg/kg IV every 8 hours) with enrofloxacin, Unasyn (22 mg/kg/IV every 8 hours)
- Gastroprotectants
- Antiemetics
 - Dolasetron (0.6 mg/kg IV every 24 hours)
 - Ondansetron (1 mg/kg IV every 8–12 hours)
 - Cerenia (1 mg/kg SQ, 2 mg/kg PO)
 - Metoclopramide (1–2 mg/kg per day IV CRI)
- H₂ blockers
 - Famotidine 0.5 to 1 mg/kg IV every 12 hours
 - Ranitidine 0.2 to 2 mg/kg IV or PO every 8 to 12 hours
 - Cimetidine 5 mg/kg IV every 6 to 8 hours
- Proton pump inhibitors
 - Omeprazole 0.5 to 1 mg/kg PO every 12 hours
 - Pantoprazole 1 mg/kg IV
- Sucralfate (0.25–1 g PO three times a day)
- Antiarrhythmic drugs
 - Lidocaine (2 mg/kg IV bolus, then 50–100 µg/kg per minute IV CRI)
 - Procainamide 6–10 mg/kg IV loading dose over 1–2 minutes, then 20–40 mcg/kg min IV CRI in 5% dextrose in water; or 10–22 mg/kg PO every 8 hours
- Dextrose (0.5 g/kg 25% dextrose IV, followed by 2.5–5% dextrose CRI)
- Seizures
 - Diazepam (0.5–1 mg/kg IV)
 - Phenobarbital loading (16–20 mg/kg IV); dose may be divided into four or five smaller doses and given every 30 minutes, provided that patient is rousable in between doses
 - Pentobarbital (3–15 mg/kg IV slowly to effect)
 - Propofol (4–7 mg/kg IV to effect, followed by 0.1–0.6 mg/kg per minute IV CRI)
- Thrombocytopenia
 - Platelet concentrate available from commercial blood banks

Contraindications

Glucocorticoids

- Although glucocorticoids reportedly can stabilize cellular membranes, there has been no documented benefit proven for their use in hyperthermic patients, and they are not recommended due to the risk of further decreasing mesenteric and renal perfusion.

Nonsteroidal Anti-Inflammatory Drugs

- NSAIDs of any form are contraindicated in heat stroke due to the risk of decreasing mesenteric and renal blood flow, and the risk of increasing GI ulceration. Dipyrone and flunixin meglumine specifically are contraindicated. Patients with exertional and nonexertional heat stroke are hyperthermic because of decreased ability to adequately dissipate heat. The mechanism of elevated body temperature is much different from that of pyrogenic hyperthermia, in which some NSAIDs may be indicated, on a case-by-case basis.

Overcooling

- Overcooling should be avoided due to the risk of overshooting and causing iatrogenic hypothermia. Hypothermia can induce shivering, which will increase the metabolic demands of the body, and can cause temperature to further increase.

Surgical Considerations

- Emergency tracheostomy may be necessary in cases of airway obstruction.



COMMENTS

Client Education

- Be aware of clinical signs.
- Educate client how to appropriately cool overheated animals prior to transport.
- An animal that has had prior episodes of heat stroke may be predisposed to additional episodes of heat stroke, even at lower environmental temperatures.

Patient Monitoring

- Monitor patients very closely when attempting to cool them and for a minimum of 24 hours afterwards because hypothermia can occur.
- Monitor the patient closely for signs of adverse sequelae, including DIC, renal failure, respiratory distress (ARDS, noncardiogenic pulmonary edema, aspiration pneumonia), and other organ failure.
- Monitor closely for renal failure secondary to rhabdomyolysis and myoglobinuria.
- Monitor parameters such as heart rate, respiratory rate and effort, blood pressure, pulse oximetry and/or arterial blood gas, body temperature, ECG, coagulation status (platelet count, PT, aPTT), BUN, creatinine, electrolytes, lactate, glucose, urinalysis to check for renal tubular casts, urine output, PCV, and total protein.

Prevention/Avoidance

- Educate clients to not confine animals to areas where they cannot escape heat (e.g., cars, tied in yard without water or shelter/shade).
- Exercise animals during the coolest portions of the day.

- Acclimate the animal to short bursts of exercise or work before a longer training or working period.
- Rest animals that are working or exercising every 30 minutes and provide access to shade and water.
- Animals that are obese, have brachycephalic airway disease, laryngeal disorders, or any other predisposing factor should avoid exercise and remain in cool environments with fans or air conditioning.

Possible Complications

- Cardiac dysrhythmias
- MODS
- DIC
- Cerebral edema
- Coma
- Seizures
- Noncardiogenic pulmonary edema
- ARDS
- Acute renal failure
- SIRS
- Rhabdomyolysis
- Hepatocellular damage
- Bacterial translocation
- Sepsis
- GI ulceration
- Respiratory arrest
- Cardiac arrest
- Death

Expected Course and Prognosis

- Favorable if survive past 24 hours with no neurologic signs at time of presentation
- Prognosis less favorable if neurologic signs (i.e., coma or progressive decline in neurologic status), hypothermic at time of initial presentation, persistent hypoglycemia, progressive worsening of azotemia, development of DIC or refractory hypotension, elevated total bilirubin, hypoproteinemia, respiratory difficulty or pulmonary edema, oliguria or anuria.
- Affected animals may have predisposition to other episodes of hyperthermia due to change in the sensitivity of the hypothalamic thermoregulatory set point.
- Prognosis more guarded in animals that present with hypothermia after cooling or neurologic signs (i.e., seizure, coma).

Synonyms

- Heat exhaustion, heat prostration, heat stroke, heat-induced illness

Abbreviations

- Alk Phos: alkaline phosphate
- ALT: alanine transaminase
- aPTT: activated partial thromboplastin time
- ARDS: acute respiratory distress syndrome
- AST: aspartate aminotransferase
- BUN: blood urea nitrogen
- CBC: complete blood count
- CK: creatine kinase
- CRI: constant rate infusion
- CT: computed tomography
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- FDP: fibrin degradation products
- GI: gastrointestinal
- IV: intramuscularly
- MODS: multiple organ dysfunction syndrome
- MRI: magnetic resonance imaging
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PCV/TS: packed cell volume/total solids
- PO: by mouth
- PT: prothrombin time
- SIRS: systemic inflammatory response syndrome
- SQ: subcutaneously
- USG: urine specific gravity

Suggested Reading

- Bouchama, A, and Knochel, JP. Heatstroke. *N Eng J Med* 2002;346:1978–1988.
- Bruchim, Y, Klement, E, Saragusty, J, Finkeilstein, E, Kass, P, and Aroch, I. Heat stroke in dogs: a retrospective study of 54 cases (1999–2004) and analysis of risk factors for death. *J Vet Int Med* 2006;20:38–46.
- Drobatz, KJ, and Macintire, DK. Heat-induced illness in dogs: 42 cases (1976–1993). *J Am Vet Med Assoc* 1996;209:1894–1899.
- Drobatz, KJ. Heat stroke. In: Silverstein, DC, and Hopper, K, eds. *Small Animal Critical Care Medicine*, pp.723–726. St. Louis: Saunders Elsevier, 2009.
- Fluornoy, WS, Wohl, JS, and Macintire, DK. Heatstroke in dogs: Pathophysiology and predisposing factors. *Comp Cont Educ Pract Vet* 2003;25:410–418.
- Fluornoy, WS, Wohl, JS, and Macintire DK. Heat stroke in dogs: clinical signs, treatment, prognosis and prevention. *Comp Cont Educ Pract Vet* 2003; 25(6):422–431.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Steven Marks

Hemoabdomen



DEFINITION/OVERVIEW

- A collection of blood within the abdominal cavity



ETIOLOGY/PATHOPHYSIOLOGY

- Blunt trauma such as automobile injury or high-rise fall
- Penetrating trauma such as dog bite wounds, gun shot wounds, knife wounds, impalement by foreign object
- Rupture of abdominal vessels secondary to gastric dilatation and volvulus or splenic torsion
- Rupture of tumor associated with abdominal organs (i.e., liver, spleen, adrenal)
- Coagulopathy either congenital or acquired (i.e., anticoagulant rodenticide toxicity, hepatic disease, hemophilia)
- Postsurgical complication (i.e., slipped ovarian ligatures)

Incidence/Prevalence

- Unknown, more common in dogs than in cats

Systems Affected

- Cardiovascular—hypotension due to blood loss, cardiac arrhythmias may occur secondary to hypoxia
- Hemic/lymphatic/immune—anemia due to blood loss, may not be apparent until fluid compartment shifts have occurred, possibly thrombocytopenia secondary to platelet consumption



SIGNALMENT/HISTORY

- Golden retriever, German shepherd, Labrador retriever, and other large-breed dogs have breed predilection for hemangiosarcoma.
- Reported higher incidence of hemangiosarcoma in male dogs

- Middle age to older dogs in general have increased incidence of hemoabdomen associated with neoplasia.
- Intact free-roaming male dogs and cats have increased risk of traumatic hemoabdomen.
- Hemoabdomen due to neoplasia is rare in cats.
- Hemoabdomen in general can be seen in any age or breed.

Risk Factors/Causes

- Free-roaming dogs and cats have increased risk for blunt and penetrating trauma that result in hemoabdomen.
- Congenital or acquired coagulopathy
- Exposure to anticoagulant rodenticides increases potential for acquired coagulopathy.
- Presence of abdominal mass, particularly spleen or liver associated, increases risk of hemoabdomen.

Historical Findings

- Weakness or ataxia
- Acute collapse
- Abdominal distension
- Depression
- Anorexia
- Vomiting
- Possible history of trauma, history of coagulopathy, or history of exposure to anti-coagulant rodenticides



CLINICAL FEATURES

- Lethargy
- Weakness
- Pale mucous membranes
- Abdominal distension with fluid wave
- Tachycardia with weak peripheral pulses
- Tachypnea
- Possibly abdominal mass
- Possibly external wounds if hemoabdomen is traumatic
- Possibly bleeding from other sites, petechiae, or ecchymoses with coagulopathy or trauma



DIFFERENTIAL DIAGNOSIS

- Peritonitis—can be differentiated on the presence of large numbers of degenerate neutrophils and the presence of bacteria on cytologic examination of abdominal fluid from animals with peritonitis.

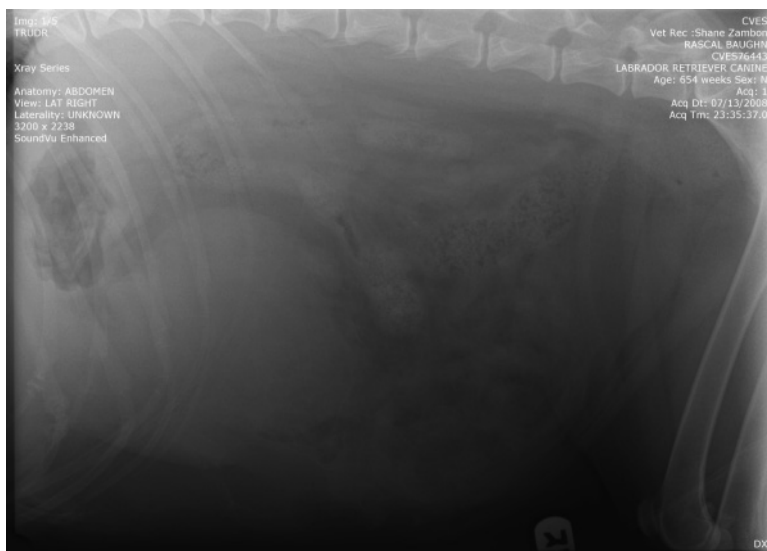
- Hypovolemic shock—may co-exist with hemoabdomen; hypovolemic shock due to other causes of fluid and blood loss may not result in abdominal effusion.
- Uroabdomen—Abdominal fluid is generally serosanguineous rather than hemorrhagic with uroabdomen, and the creatinine, BUN and potassium of the abdominal fluid will be higher than that of peripheral blood.
- Splenic torsion—Hemoabdomen may occur secondary to splenic torsion but is not present in all cases. Best differentiated on basis of abdominal ultrasound.
- Immune-mediated hemolytic anemia—differentiated by the absence of abdominal fluid and by evidence of immune-mediated red blood cell destruction on complete blood count (RBC agglutination, spherocytosis).



DIAGNOSTICS

Complete Blood Count

- Anemia but only after enough time has elapsed for fluid shifts to occur (several hours). With acute hemorrhage, patient may appear hypovolemia but not be anemic.
- Leukocytosis may be noted due to stress, neoplasia, or trauma. Thrombocytopenia may be noted due to platelet consumption. Primary thrombocytopenia may rarely cause hemoabdomen.
- Chemistry panel—Hypoalbuminemia may occur secondary to blood loss.
- Coagulation panel—Elevations in PT and/or PTT may indicate underlying congenital or acquired coagulopathy or DIC occurring secondary to abdominal hemorrhage. In one study 84 percent of dogs with nontraumatic hemoabdomen had a secondary coagulopathy.
- Abdominal radiographs—Generally not very rewarding as the presence of abdominal fluid causes a generalized loss of detail although a mass effect may be seen with neoplasia.
- Abdominocentesis
 - Can be “blind” four quadrant or ultrasound guided. May reveal the presence of nonclotting blood (or other fluid) within the abdominal cavity; positive abdominocentesis indicates that there is >5 ml/kg of blood within the abdominal cavity.
 - Clotting of the blood indicates either rapid, ongoing hemorrhage or perforation of a vessel or organ during the abdominocentesis procedure.
 - PCV/TS of abdominal fluid—PCV of abdominal fluid will be greater than that of peripheral blood if active bleeding is occurring.
- DPL
 - May be helpful if abdominocentesis is negative.
 - Instill 10 to 22 ml/kg of warm fluid into the abdomen using a large-bore, multiply fenestrated over-the-needle catheter, distribute fluid by rotating or walking the patient, then aspirate fluid back by routine abdominocentesis.
 - PCV > 5% is indicative of hemorrhage; serial hematocrits can be performed on DPL fluid to assess for ongoing hemorrhage.



■ **Figure 43.1** This abdominal radiograph shows a mass effect in the cranial to mid-abdomen and mild loss of abdominal detail consistent with abdominal fluid. This patient was diagnosed with a splenic mass on ultrasound, and free abdominal fluid was noted.

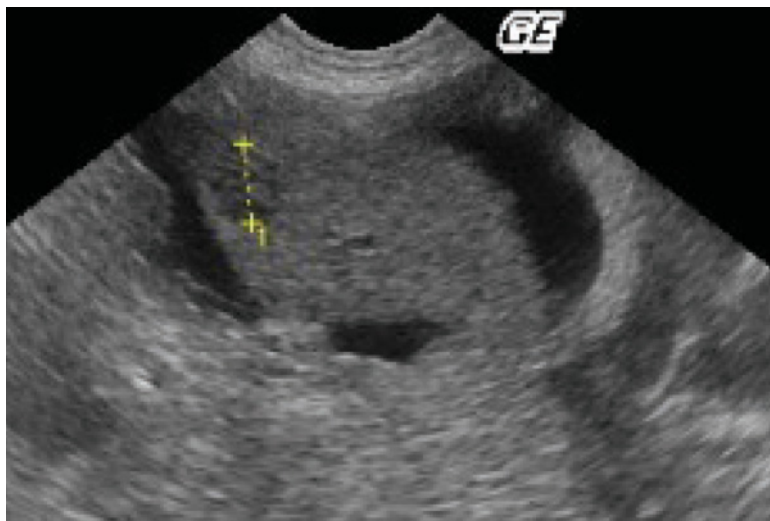
- Abdominal ultrasound
 - Very sensitive (96 percent) in detecting abdominal fluid.
 - Useful for guiding abdominocentesis and evaluating for primary and metastatic abdominal masses.
- Thoracic radiographs
 - Should be performed with any bleeding abdominal mass to evaluate for metastasis and should be performed with blunt trauma to evaluate for concurrent thoracic injury or diaphragmatic hernia.

Pathological Findings

- Vary depending on the cause for hemoabdomen.
- Other traumatic injuries may be present with blunt or penetrating trauma.
- With neoplasia, mass of liver, spleen, or adrenal gland may be noted and possibly evidence of metastatic disease.
- With coagulopathy, hemorrhage in other areas may be noted.

Histopathologic Findings

- Vary depending on underlying cause.
- With neoplasia, hemangiosarcoma of the spleen is the most common tumor causing hemoabdomen but benign splenic hematoma, hepatocellular carcinoma, and adrenal adenocarcinoma can also result in hemoabdomen.



■ **Figure 43.2** Abdominal ultrasound is quite sensitive in detecting free abdominal fluid and can be used to guide abdominocentesis as well as to evaluate for a cause of hemorrhage. This patient has free fluid within the abdomen and a splenic mass, noted with the yellow markers.



THERAPEUTICS

- Treat hemorrhagic shock by administration of supplemental oxygen and intravenous fluids.
- Isotonic crystalloids (lactated Ringer's solution, Normosol-R, Plasmalyte-A) can be administered at shock dosages (up to 90 ml/kg in the dog and 50 ml/kg in the cat).
- Fluid administration should be titrated to reach a systolic blood pressure of approximately 80 mm Hg.
- Synthetic colloids such as Hetastarch can be administered at 10 to 20 ml/kg in 5 ml/kg incremental doses.
- Transfusion with packed red blood cells (11 ml/kg) should be utilized to maintain PCV above 25 percent.
- Hemoglobin based oxygen carriers (such as oxyglobin 5–10 ml/kg) can also be utilized to treat hemorrhagic shock.
- Treat underlying primary or secondary coagulopathies.
 - Fresh frozen plasma (10–15 ml/kg) is used to restore clotting factors.
 - Vitamin K1 should be administered with hepatopathy or Vitamin K antagonist rodenticide toxicity.
- Control hemorrhage.
 - External counterpressure can be applied by using towels secured with tape to wrap the hind limbs, pelvis, and abdomen starting at the hind feet. Avoid excessive pressure (bandage should be loose enough to fit your hand underneath) to avoid intestinal ischemia and monitor for respiratory compromise. Leave bandage in place 2 to 4 hours then gradually remove over 8 to 12 hours.



■ **Figure 43.3** A compression bandage has been applied to the hind limbs, pelvis, and abdomen of this patient to help control abdominal hemorrhage.

- Surgery on an emergent basis is indicated with bleeding abdominal masses and penetrating abdominal wounds.
 - Surgery is indicated with blunt trauma if the patient is not responding to fluid resuscitation, the abdominal PCV is rising, and there is progressive abdominal distension despite appropriate resuscitative measures.
 - Abdominal exploratory is rarely required in cases of traumatically induced hemoabdomen.
 - Surgery is contraindicated in patients with primary coagulopathy.
- Control pain from trauma or surgery using fentanyl CRI (2–5 µg/kg per hour), hydromorphone (0.1–0.2 mg/kg IV or SQ every 6–8 hours), or morphine (Dog: 0.1–0.5 mg/kg per hour IV CRI or 0.05–0.1 mg/kg IV every 3–4 hours, 0.2–1 mg/kg IM or SQ every 4–6 hours).
- Prevent infection in the case of penetrating abdominal wounds.
 - Clean and bandage the wounds.
 - Administer antibiotics (cefazolin 22 mg/kg IV every 6–8 hours).
 - With gastrointestinal visceral or bite wounds the antibiotic spectrum should be expanded to include anaerobic organisms using cefoxitin (20–30 mg/kg IV every 6–8 hours), ampicillin/sulbactam (20 mg/kg IV every 8 hours), or a combination of ampicillin (22 mg/kg IV every 6–8 hours) with enrofloxacin (5–10 mg/kg IV every 24 hours).

Precautions/Interactions

- Avoid aspirin and other nonsteroidal anti-inflammatory medications that decrease platelet function and can decrease renal perfusion in the face of hypovolemia.
- Hypertension should be avoided, as this can lead to disruption of clot formation and increased hemorrhage. Generally, resuscitation to low normal blood pressure

(between 80 and 110 mmHg systolic) is considered optimal in order to maintain organ and tissue perfusion but avoid exacerbation of bleeding.

Activity

- Usually limited in order to allow recovery from abdominal surgery or to prevent further bleeding in cases of coagulopathy.

Surgical Considerations

- Emergent surgery is recommended for patients with bleeding abdominal masses and penetrating abdominal wounds.
- Surgery is indicated in blunt trauma patients who are not responding to fluid resuscitation or with rising abdominal PCV and progressive abdominal distension.
- These patients are often hemodynamically unstable and fluctuations in blood pressure and heart rate may complicate anesthesia.



COMMENTS

Client Education

- Client should be informed of cost and prognosis associated with treatment based on underlying cause for hemoabdomen.

Patient Monitoring

- Assess blood pressure frequently (every 5 minutes) until patient is stable then gradually less often after the patient stabilizes.
- Electrocardiogram is recommended continuously or at least every 3 to 4 hours for the first 24 hours in patients with abdominal or thoracic trauma or who have undergone splenectomy.
- PCV/TS may need to be monitored every 4-6 hours initially.
- Coagulation panel is needed, particularly in patients with existing coagulopathy (either primary or secondary).

Prevention/Avoidance

- Abdominal masses cannot be prevented but surgical removal as soon as they are identified can prevent onset of bleeding.
- Avoid allowing pets to roam free, which increases the potential for trauma and access to anticoagulant rodenticides.

Possible Complications

- Hemorrhage
- Cardiac dysrhythmias
- DIC

Expected Course and Prognosis

- Varies depending on underlying cause of hemoabdomen and on presence of co-existing injuries in cases of trauma.
- Prognosis in general is guarded to fair.
- Patients with hemoabdomen that are anemic and have a splenic mass have a 76 percent likelihood of malignant neoplasia.
 - With hemangiosarcoma, microscopic metastasis has typically occurred prior to the time of presentation.
 - Median survival times of 2 to 3 months with surgery and 4 to 6 months with adjunctive chemotherapy have been reported; common sites for metastasis include the liver and right atrium.

Synonyms

- Hemoperitoneum

Abbreviations

- BUN: blood urea nitrogen
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- DPL: diagnostic peritoneal lavage
- IM: intramuscularly
- IV: intravenously
- PCV/TS: packed cell volume/total solids
- PT: prothrombin time
- PTT: partial thromboplastin time
- RBC: red blood cell
- SQ: subcutaneously

Suggested Reading

- Gfeller, RW. An intensivist's approach to hemoabdomen. *Proceedings of the 20th Annual ACVIM Forum*, May 29–June 1, 2002, pp.14–16.
- Hammond, TN, and Pesillo-Crosby, SA. Prevalence of hemangiosarcoma in anemia dogs with a splenic mass and hemoperitoneum requiring a transfusion: 71 cases (2003–2005). *J Am Vet Med Assoc* 2008;232(4):553–558.
- Plunkett, SJ. *Emergency Procedures for the Small Animal Veterinarian*, 2nd ed., pp. 127–129. London: WB Saunders, 2001.
- Vinavak, A, and Krahwinkel, DJ. Managing blunt trauma-induced hemoperitoneum in dogs and cats. *Compend Contin Educ Pract Vet* 2004;26(4):276.

Author: Teresa Dye

Hepatic Encephalopathy (HE)



DEFINITION/OVERVIEW

- Clinical syndrome of neurologic and cognitive dysfunction that result from the metabolic consequences of congenital or acquired liver disease.
- Represents a continuum of clinical signs from mild, subtle abnormalities to severe neurologic disease.



ETIOLOGY/PATHOPHYSIOLOGY

- Due to (1) CPSS, (2) APSS, or less commonly (3) fulminant hepatic failure.
- CPSS is the most common cause in small animals.
- Hyperammoniaemia is a key pathophysiological mechanism.
- Ammonia is generated from amino acids in diet, catabolism of glutamine by enterocytes, or from peripheral tissue (e.g., skeletal muscle). Urease-producing bacteria in the GI tract degrade urea into ammonia. In health, the liver efficiently removes ammonia from the portal circulation and detoxifies it to urea and glutamine.
- Hyperammoniaemia induces neurologic dysfunction by: (1) causing astrocyte swelling (low-grade cerebral edema), (2) inducing oxidative injury to astrocytes, and (3) sensitizing the CNS to other precipitating factors of HE. This ultimately affects CNS gene expression, protein/mRNA modification, cell signaling, and finally astrocyte and neuronal function resulting in clinical HE.
- Severity of HE does not always correlate with degree of hyperammoniaemia likely because other factors exacerbate astrocyte swelling and oxidative injury.

Systems Affected

- Nervous—Primary system affected by HE. Cerebral dysfunction is common (e.g., behavioral changes, altered mentation) but multifocal and lateralizing neurologic deficits and seizures can also occur.
- GI—decreased appetite (can rarely be increased), vomiting, diarrhea, and weight loss can be due to central effects of HE or underlying liver disease.
- Urinary—PU/PD due to primary PD and/or primary PU (nephrogenic diabetes insipidus). Lower urinary tract signs are also possible as a result of secondary infection or ammonium biurate stone formation.



SIGNALMENT/HISTORY

- Median age of dogs diagnosed with CPSS is 12 months; 37 percent of dogs with CPSS are older than 2 years of age.
- The majority (~89 percent) of dogs with CPSS are small breeds.
- CPSS has been shown to be heritable in the Yorkshire terrier, Cairn terrier, and Irish wolfhound; heritability is suspected in other breeds.
- Increased risk for CPSS in the Havanese, Yorkshire terrier, Maltese, and pug breeds.
- For cats, CPSS occurs most commonly in the domestic shorthair.
- APSS are typically found in older animals although any age may be affected.

Risk Factors/Causes

- High protein meal, GI bleeding (e.g., ulceration, coagulopathy, GI parasites), infection, sedatives/anesthesia, diuretics, electrolyte disturbances (e.g., acidosis, hyponatremia, hypokalemia), trauma, azotemia, stored blood transfusion

Historical Findings

- Vague, episodic abnormalities are common such as lethargy, depression, and changes in personality or behavior.
- Clinical signs may worsen after a meal.
- Neurologic abnormalities (seizures are uncommon)
- For CPSS, poor growth and small body stature
- For APSS, weight loss and poor body condition
- Vomiting, diarrhea, and decreased appetite
- Poor tolerance of sedation/anesthesia
- PU/PD, dysuria, hematuria, urinary obstruction
- Cats: ptyalism



CLINICAL FEATURES

- Neurologic deficits: ataxia, pacing/wondering, circling, long tract deficits, head pressing, cortical blindness, head/muscle tremors, unresponsiveness/coma, multifocal or lateralizing deficits, vestibular disease
- Ascites with APSS
- Fever
- Poor body condition
- Melena
- Cats—ptyalism, golden-copper colored iris, hepatomegaly in hepatic lipidosis



DIFFERENTIAL DIAGNOSIS

- Neurologic disease—hypoglycemia, toxins (lead, ethylene glycol), congenital neurologic disease (hydrocephalus), thiamine deficiency (cats), drug toxicity, neoplasia, inflammatory/infectious CNS disease
- GI disease—other primary GI disease
- Urinary symptoms—urolithiasis, UTI, neoplasia



DIAGNOSTICS

- Bile acids (resting, pre and post-prandial)—an abnormal postprandial bile acid concentration should always be present in HE. It is possible to have normal resting/fasting bile acids test in the presence of severe liver disease.
- Blood ammonia (resting, post-prandial, ammonia tolerance)—degree of elevation may not correlate with degree of HE. Resting ammonia abnormal in 62 to 88 percent of animals with PSS. Strict sample handling required to prevent false-negative results. Worsening of clinical signs may occur with ammonia tolerance test.
- Serum chemistry—evidence of decreased liver function commonly present (i.e., hypoalbuminemia, low BUN, hypocholesterolemia, hypoglycemia), liver enzyme elevation (absent or mild with CPSS), and hyperbilirubinemia (uncommon with CPSS)
- Complete blood count—decreased MCV common with CPSS, may also be seen with APSS. Mild nonregenerative normochromic anemia and variable leukocytosis may also occur. Target cells (dogs)
- Urinalysis—ammonium biurate crystals (26–57 percent dogs and 16–42 percent cats CPSS), iso/hyposthenuria
- Ultrasound—operator-dependent sensitivity and specificity for diagnosis of CPSS (80 percent sensitivity, 66.7 percent specificity for extrahepatic CPSS; 100 percent sensitivity for intrahepatic CPSS). Dilated left gonadal vein is consistent with portal hypertension and APSS.
- Other imaging to identify PSS: portography, scintigraphy
- Protein C—decreases with PSS and liver failure
- Clotting profile (PTT, PT, activated clotting time)



THERAPEUTICS

- Objectives of treatment are to: (1) decrease systemic absorption of ammonia from the GI tract, (2) identify and correct precipitating factors, (3) minimize bacterial interaction with nitrogenous substances, and (4) treat complications association with decreased liver function.

- For emergency therapy of HE, several concurrent treatments should be given (e.g., fluid therapy, lactulose, antibiotics, and enemas).
- For chronic therapy, a single treatment such as antibiotic therapy may be sufficient.
- Nonabsorbable disaccharides—alter bacterial flora, decrease absorption of ammonia, cathartic. Lactulose may be given orally or as an enema. Oral dose: 5 to 15 ml three times a day (dog), 0.25 to 1 ml three times a day (cat); adjust dose to achieve soft stools. Retention enema: 20 to 30 ml/kg, one part lactulose to two parts water, leave for 20 to 30 minutes
- Antibiotic therapy—decreases ammonia producing enteric bacteria. Neomycin oral dose: 22 mg/kg PO three times a day (dog and cat), retention enema: 10 to 20 mg/kg diluted in water after cleansing enema. Metronidazole (7.5 mg/kg twice a day) or amoxicillin (22 mg/kg twice a day) are alternative antibiotics.
- Enemas—bowel cleansing to decrease ammonia production. Warm water cleansing enema(s) until colonic contents evacuated followed by retention enema (lactulose, neomycin, or 10% povidone iodine)
- Fluid therapy to correct dehydration and electrolytes
- For seizures: correct hypoglycemia, diazepam (0.5–2 mg/kg IV)
- Fulminant hepatic failure/cerebral edema: mannitol, furosemide, with or without steroids

Precautions/Interactions

- Avoid NSAIDs due to risk of GI ulceration
- Caution with drugs metabolized by liver
- Oral neomycin rarely causes ototoxicity, nephrotoxicity, severe diarrhea, and intestinal malabsorption.

Alternative Drugs

- Flumazenil (0.02 mg/kg IV)—BZD antagonist, for unresponsive HE, blocks endogenous BZD.
- Sarmazenil (3–8 mg/kg IV, dogs, experimental)—BZD partial inverse agonist, for unresponsive HE, blocks increased GABAergic tone.
- Oral branched chain amino acids
- Stimulation of urea and glutamine synthesis (zinc, L-ornithine aspartate)

Diet

- In severe or emergent cases, withhold food to decrease protein load and prevent aspiration in patients with altered consciousness.
- Commercial diet specifically formulated for liver disease is recommended (e.g., Hill's l/d).
- Feed small amounts of food several times daily.
- Maintaining weight and muscle mass is critically important; skeletal muscle is a major site of ammonia detoxification with decreased liver function.

- Use of a low protein diet is no longer recommended in people; it is possible that this may lead to weight loss and worsening of the patient's clinical condition.
- Hepatic lipidosis (cats): feeding a well-balanced diet containing arginine is crucial to reverse lipidosis and subsequently HE.

Surgical Considerations

- Surgical correction of CPSS is recommended for definitive treatment.
- Postoperatively, 10 percent incidence complications, 7.1 percent mortality, 80 percent excellent outcome, 6 percent poor outcome
- Transvenous coil embolization is a minimally invasive alternative to surgery; this is not widely available.
- Caution with anesthesia/sedatives; reversible pre-anesthetics are recommended (e.g., opioids, BZDs)



COMMENTS

- Repeated, directed physical examinations are crucial to identify underlying risk factors such as any local/systemic infection or GI bleeding (e.g., rectal examination for melena).

Expected Course and Prognosis

- HE temporarily reversible with medical therapy
- Dogs with CPSS managed medically survived an average of 9.9 months; complete cure possible with surgery
- Poor long term prognosis for APSS
- Poor short-term prognosis for fulminant hepatic failure, but recovery possible

Synonyms

- Portosystemic encephalopathy
- Hepatic coma

Abbreviations

- APSS: acquired portosystemic shunt
- BUN: blood urea nitrogen
- BZD: benzodiazepine
- CNS: central nervous system
- CPSS: congenital portosystemic shunt
- GI: gastrointestinal
- HE: hepatic encephalopathy
- IV: intravenously
- MCV: mean cell volume

- mRNA: messenger ribonucleic acid
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- PSS: portosystemic shunt
- PT: prothrombin time
- PTT: partial thromboplastin time
- PU/PD: polyuria/polydipsia
- UTI: urinary tract infection

Suggested Reading

Broome, CJ, Walsh, VP, and Braddock, JA. Congenital portosystemic shunts in dogs and cats. *NZ Vet J* 2004;52(4):154–162.

Windsor, RC, and Olby, NJ. Congenital portosystemic shunts in five mature dogs with neurological signs. *J Am Anim Hosp Assoc* 2007;43:322–331.

Author: Anthony T. Gary

Hyperglycemia



DEFINITION/OVERVIEW

- Abnormally high blood glucose concentration



ETIOLOGY/PATHOPHYSIOLOGY

- Insulin deficiency
- Increased hepatic gluconeogenesis
- Decreased consumption of glucose in peripheral tissues
- Increased glycogenolysis
- Excess of glucocounterregulatory hormones such as cortisol, ACTH, growth hormone, epinephrine, and glucagon

Systems Affected

- Metabolic—regulation of excess carbohydrate metabolism
- Renal—polyuria secondary to hyperglycemic osmotic diuresis
- Nervous—Severe hyperglycemia leads to hyperosmolality that may cause CNS dysfunction.
- Ophthalmic—cataracts in dogs secondary to persistent hyperglycemia



SIGNALMENT/HISTORY

- Variable depending on underlying cause

Risk Factors/Causes

- Low glucose use, insulin deficiency, or insulin antagonism
 - Diabetes mellitus
 - Pancreatitis

- Acromegaly (cat)
- Diestrus (bitch)
- Increased glucose production
 - Hyperadrenocorticism
 - Pheochromocytoma
 - Glucagonoma
 - Exocrine pancreatic neoplasia
- Insulin administration problems in confirmed diabetics
 - Insulin overdosage
 - Somogyi phenomenon
 - Insulin resistance
 - Poor absorption of insulin
- Physiologic
 - Stress hyperglycemia (especially in cats)
 - Postprandial (diets containing monosaccharides or disaccharides)
- Drugs
 - Glucocorticoids
 - Progestagens
 - Megestrol acetate
 - Thiazide diuretics
- Iatrogenic
 - Excessive dextrose containing fluids
 - Parenteral nutrition
- Other
 - Renal insufficiency—Decreased renal clearance of glucose in diabetic animals can lead to severe hyperglycemia. Also, decreased tissue utilization can occur.
 - Head trauma
- Concurrent disease—hyperadrenocorticism, pancreatitis
- Obesity
- Diabetogenic drugs
- Dextrose-containing fluids



CLINICAL FEATURES

- Clinical features are variable due to underlying cause. Many animals are asymptomatic.
 - Polyuria
 - Polydipsia
 - Polyphagia
 - Weight loss
 - CNS depression can be seen with severe hyperglycemia.



DIFFERENTIAL DIAGNOSIS

- Mild, transient high blood glucose; rule out stress and postprandial fluctuation
 - Recheck after 12-hour fast.
 - Recheck after minimizing stress; acclimate to hospital environment or consider home blood glucose monitoring.

Laboratory Findings

- Drugs that may alter laboratory results
 - High blood glucose concentrations—glucocorticoids, ACTH, dextrose-containing fluids, epinephrine, asparaginase, β -adrenergic agonists, and diazoxide
- Disorders that may alter laboratory results
 - Lipemia, hemolysis, or icterus may interfere with spectrophotometric assays.
 - Delayed serum separation may falsely lower blood glucose results due to cellular glucose use; separate within 1 hour of collection.
 - Refrigerate or freeze serum samples not analyzed within 12 hours.
 - Blood glucose reagent strips used in home monitoring require whole blood samples.
- Valid if run in human laboratory



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- CBC is usually normal in the uncomplicated diabetic patient.
- Biochemistry panel
 - Hyperglycemia
 - Hypercholesterolemia
 - Lipemia may be secondary to low lipoprotein lipase, hyperadrenocorticism, pancreatitis, or postprandial blood sampling.
 - Increased ALT (usually <500 IU/L) due to hepatic lipidosis
 - Increased Alk Phos (usually <500 IU/L) due to hepatic lipidosis
 - Amylase and lipase have low specificity for concurrent pancreatitis.
- Urinalysis
- USG usually >1.025
- Glucosuria in diabetes mellitus
- Variable ketonuria
- Bacteriuria and pyuria possible if concurrent urinary tract infection

Other Laboratory Tests

- Serum fructosamine concentration—marker of mean blood glucose concentration over the past 1 to 3 weeks. A normal fructosamine concentration in a hyperglycemic

patient supports transient, or stress-related hyperglycemia. Also used to monitor glycemic control in the diabetic patient. May be falsely lowered by hypoalbuminemia, hyperlipidemia, and azotemia.

- Blood glycosylated hemoglobin concentration—marker of mean blood glucose concentration over the past 3 to 4 months.
- Serum insulin concentration—rarely analyzed. Hyperglycemia should be accompanied by hyperinsulinemia in a normal patient. Hypoinsulinemia in the presence of hyperglycemia suggests diabetes mellitus.
- ACTH-stimulation test or low dose dexamethasone suppression test to rule out concurrent hyperadrenocorticism
- PLI—species specific test. Positive result suggestive of concurrent pancreatitis
- Intravenous glucose tolerance test, intravenous glucagons tolerance test—rarely indicated.

Imaging

- Abdominal ultrasound may be useful in identifying underlying causes (i.e., hyperadrenocorticism, pancreatitis).



THERAPEUTICS

- Insulin therapy for confirmed diabetic patients
- Avoid rapid decrease in blood glucose levels.
- Discontinue diabetogenic drugs.
- Dextrose-free fluids
- Dietary therapy
 - Cats—feed low carbohydrate, high protein canned foods
 - Dogs—feed high fiber, low fat diet

Drug(s) of Choice

- Insulin
 - Regular (crystalline) insulin has a rapid onset of effect but short duration of action. Most useful in the hospital setting in the anorexic or ketotic patient
 - Intermediate and long acting insulins (i.e., NPH, PZI, glargine, vetsulin) are used in the long-term management of diabetics.

Contraindications

- Diabetogenic drugs
- Dextrose-containing fluids

Precautions/Interactions

- Avoid rapid lowering of blood glucose levels.
- Avoid hypoglycemia.

Alternative Drugs

- Oral hypoglycemic agents (sulfonylureas such as glipizide) are more useful in type II (noninsulin dependent) diabetic cats. However, response to these medications is poor and adverse side effects are common.



COMMENTS

Patient Monitoring

- Recheck blood glucose after minimizing stress, discontinuing diabetogenic drugs to confirm diagnosis.
- Glucose curves measuring blood glucose concentration every 2 hours after insulin administration can be performed in the hospital or at home by the owner using a blood glucose monitoring system.
- Serum fructosamine concentration and glycosylated hemoglobin monitor long-term glucose control.
- Monitor for return of clinical signs: weight loss, polyuria, polyphagia, and polydipsia.

Possible Complications

- High incidence of infection (especially urinary tract infections and skin infections)
- Severe hyperglycemia may be associated with CNS depression and coma because of hyperosmolarity.
- Hypoglycemia may result as an effect of too aggressive therapy for hyperglycemia.

Associated Conditions

- Severe hyperglycemia is associated with hyperosmolarity.
- Diabetic ketoacidosis—hyperglycemia, acidosis and low total body concentrations of sodium, potassium, and phosphorus

Pregnancy

- Pregnancy-related diabetes mellitus caused by high progesterone concentrations is reported in humans.

Synonyms

- High blood sugar

Abbreviations

- ACTH: adrenocorticotrophic hormone
- Alk Phos = alkaline phosphatase
- ALT: alanine aminotransferase

- CBC: complete blood count
- CNS: central nervous system
- NPH: neutral protamine hagedorn
- PLI: pancreatic lipase immunoreactivity
- USG: urine specific gravity
- PZI: protamine zinc insulin

Author: Maureen D. Finke

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Margaret R. Kern

Hyperosmolarity



DEFINITION/OVERVIEW

- Osmolarity—expressed in mOsm/L represents the number of particles per liter of solution
- Osmolality—expressed in mOsm/kg; represents the number of particles per kilogram or solution
- Hyperosmolarity—a high concentration of particles per liter of solution
- Serum concentrations >310 mOsm/L in dogs and 330 mOsm/L in cats are considered hyperosmolar



ETIOLOGY/PATHOPHYSIOLOGY

- Serum sodium is responsible for most of the osmotically active particles that contribute to serum osmolarity; serum glucose and urea also contribute to serum osmolarity.
- Anything that causes water loss increases concentrations of solutes in plasma or serum, thereby increases serum osmolarity
- Blood volume, hydration status, and ADH secretion are intimately involved in controlling extracellular fluid volume.
- Low circulating blood volume stimulates carotid and aortic baroreceptors to respond to changes in blood pressure, causing the secretion of ADH.
- Hyperosmolarity affects the osmoreceptors in the hypothalamus and stimulates ADH secretion from the neurohypophysis; the hypothalamic thirst center is also stimulated and causes an increase in water consumption to counteract the serum hyperosmolarity by solute dilution.
- Rapid increases in serum osmolarity cause water movement across its concentration gradient from intracellular to extracellular spaces, resulting in neuronal dehydration, cell shrinkage, and cell death; cerebral vessels may weaken and hemorrhage.

Systems Affected

- Nervous—excessive thirst may be the first sign of hyperosmolarity. Central nervous depression may lead to coma.
- Cardiovascular—hypotension and decreased ventricular contractility
- Renal/urologic—low urine output (<1 – 2 ml/kg per hour)



SIGNALMENT/HISTORY

Dogs and Cats

- Hypodipsia and hyperosmolarity have been reported in young female miniature schnauzers.

General Comments

- Primarily neurologic or behavioral
- Severity is related more to how quickly hyperosmolarity occurs than to the absolute magnitude of the change.
- More likely to occur if serum osmolarity is >350 mOsm/L and usually severe if >375 mOsm/L

Historical Findings

- Anorexia, lethargy, vomiting, weakness, disorientation, ataxia, seizures, and coma
- Polydipsia followed by hypodipsia

Physical Examination Findings

- Normalities or abnormalities may reflect underlying disease.
- In addition to historical findings, dehydration, tachycardia, hypotension, weak pulses, and fever may be detected.

Increased Solutes

- Hypernatremia, hyperglycemia, severe azotemia, ethylene glycol toxicity, salt poisoning, sodium phosphate enemas in cats and small dogs, radiographic contrast solution, administration of ethanol, aspirin toxicosis, shock, lactate in patients with lactic acidosis, acetoacetate and β -hydroxybutyrate in patients with ketoacidosis, liquid enteral nutrition, and parenteral nutrition solutions.

Decreased Extracellular Fluid Volume

- Dehydration—gastrointestinal loss, cutaneous loss, third space loss, low water consumption, and polyuria without adequate compensatory polydipsia

Risk Factors/Causes

- Medical conditions that predispose—renal failure, diabetes insipidus, diabetes mellitus, hyperadrenocorticism, hyperaldosteronism, and heat stroke
- Therapeutic hyperosmolar solutions, hypertonic saline, sodium bicarbonate, sodium phosphate enemas in cats and small dogs, mannitol, and parenteral nutrition solutions
- High ambient environmental temperatures
- Fever



DIFFERENTIAL DIAGNOSIS

- Primary CNS disease and neoplasia may be characterized by altered mentation, but serum osmolality is normal.
- Physical evidence or history of injury usually helps to rule out CNS depression caused by cranial trauma.
- Perform a thorough physical examination to assess hydration and obtain information regarding previous therapy that may have included sodium-containing fluids of hyperosmolar solutions.

Laboratory Findings

Drugs That May Alter Laboratory Results

- Excessive administration of sodium-containing fluids or hyperosmolar solutions increase serum osmolality.
- Valid if run in human laboratory



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- High PCV, hemoglobin, and plasma proteins in dehydrated patients; serum electrolytes may also be increased.
- Hyperosmolality is an indication to evaluate serum sodium and glucose concentrations.
- Without the presence of excessive unmeasured osmoles, estimated serum osmolality may be calculated from serum chemistries as follows:

$$1.86(\text{Na} + \text{K}) + \text{BUN} + \text{glucose} / 2.8 \times 18$$

- Normally, calculated osmolality should not exceed measured osmolality; if it is, it is considered a laboratory error.
- If measured osmolality exceeds the calculated osmolality, determine the osmolar gap.
- Osmolar gap is equal to measured osmolality less calculated osmolality.
- High measured osmolality and normal calculated osmolality with a high osmolar gap indicate the presence of unmeasured solutes (not Na, K, BUN, or glucose).
- High measured osmolality and high calculated osmolality with a normal osmolar gap usually indicate that the hyperosmolality is caused by hyperglycemia or hypernatremia.
- Serum sodium concentration may be artifactually low in patients with severe hyperglycemia and hyperosmolality.
- Fasting hyperglycemia and glucosuria is supportive of a diagnosis of diabetes mellitus.

- Numerous calcium oxalate crystals in the urine suggest ethylene glycol toxicosis.
- High urine specific gravity rules out diabetes insipidus.
- Low urine specific gravity, especially hyposthenuria, suggests diabetes insipidus.

Other Laboratory Tests

- Urine osmolality lower than serum osmolality suggests diabetes insipidus; concentrated urine rules out diabetes insipidus.

Imaging

- Renal ultrasonography may reveal bright, hyperechoic kidneys in patients with ethylene glycol toxicosis.



THERAPEUTICS

- Mild hyperosmolality without clinical signs may not warrant specific treatment, but diagnose and treat underlying diseases.
- Hospitalize patients with moderate to high osmolality ($> 350 \text{ mOsm/L}$) and patients exhibiting clinical signs and gradually lower serum osmolality with intravenous fluids while a definitive diagnosis is pursued.
- Administer D5W or 0.45% NaCl slowly IV.
- Free water deficit can be calculated by the following formula:
 - Free water deficit less $0.4 \times \text{lean body weight in kg} \times (\text{Plasma Na}/140) - 1$
 - The goal is to not drop sodium more than 15 mEq/L in an 8-hour period; that is, the ultimate goal is to not drop the sodium by more than 2 mEq/L per hour.
 - Initially, 0.9% NaCl may be used to restore normal hemodynamics and replace dehydration deficits, replace half of dehydration deficits over 12 hours, and the remainder over 24 hours, then switch to D5W or 0.45% NaCl.

Drug(s) of Choice

- Seizures can be controlled with diazepam, phenobarbital, pentobarbital, or propofol.

Contraindications

- Hypertonic saline and hyperosmolar solutions

Precautions/Interactions

- May use 0.9% NaCl initially, but rapid administration may worsen neurologic signs
- Rapid administration of hypotonic solutions (e.g., D5W, 0.45% NaCl) may also worsen neurologic signs.

Alternative Drugs

- Regular insulin (0.1 unit/kg) IM or IV can be administered if a hyperglycemic crisis occurs secondary to parenteral nutrition administration.



COMMENTS

Patient Monitoring

- Hydration status, avoid overhydration
- Bladder size, urine output, and breathing patterns during intravenous fluids administration
- Anuria, irregular breathing patterns, worsening depression, coma, or seizures may be signs of deterioration.

Possible Complications

- Altered levels of consciousness and abnormal behavior

Associated Conditions

- Hypernatremia and hyperglycemia

Abbreviations

- ADH: antidiuretic hormone
- BUN: blood urea nitrogen
- CNS: central nervous system
- IM: intramuscularly
- IV: intravenously
- K: potassium
- Na: sodium
- NaCl: sodium chloride
- PCV: packed cell volume

Suggested Reading

Barr, JM, Khan, SA, McCullough, SM, and Volmer, PA. Hypernatremia secondary to homemade play-dough ingestion in dogs: a review of 14 cases from 1998–2001. *J Vet Emerg Crit Care* 2004;14(3):196–202.

DiBartola, SP, ed. *Fluid therapy in Small Animal Practice*. Philadelphia: Saunders, 2000.

Dibartola, SP, Green, RA, and Autran de Morais, HS. Osmolarity and osmol gap. In: Willard, MD, Tveden, H, and Turnwald, GH, eds. *Small Animal Clinical Diagnosis by Laboratory Methods*, 2nd ed., pp. 106–107. Philadelphia, Saunders, 1994.

Moens, NMM, and Remedios, AM. Hyperosmolar hyperglycemic syndrome in a dog resulting from parenteral nutrition overload. *J Am Anim Pract* 1997;38 417–420.

Author: Elisa M. Mazzaferro

Hypertension



DEFINITION/OVERVIEW

- Systemic hypertension is an elevation of systemic arterial blood pressure.
- Systemic hypertension is of concern when the elevation of blood pressure is persistent and causing or likely to cause target organ damage.



ETIOLOGY/PATHOPHYSIOLOGY

- Systemic hypertension may be stress related (i.e., “situational” or “white coat” hypertension), idiopathic (no identifiable cause), or occur as a complication of another systemic disease (“secondary” hypertension).
- Secondary hypertension is the most common form of systemic hypertension in dogs and cats. The most common diseases associated with systemic hypertension are:
 - Dogs:
 - Acute or chronic renal failure
 - Protein-losing (glomerular) renal diseases
 - Hyperadrenocorticism
 - Diabetes mellitus
 - Pheochromocytoma
 - Cats:
 - Renal disease of any variety
 - Hyperthyroidism
 - More rare causes in both species include
 - Hyperaldosteronism (cats)
 - Acromegaly (cats)
 - Sex hormone abnormalities (dogs)
- Pathogenesis is unclear in most diseases. Both cardiac output and systemic vascular resistance affect blood pressure, and alterations in either of these parameters (or their contributing components) can lead to systemic hypertension.

Systems Affected

- Any vascular bed may sustain damage from acute or chronic systemic hypertension. Most commonly affected organ systems include:
 - Eyes
 - Kidneys
 - Brain
 - Heart/vascular system
- Ophthalmologic Effects (“hypertensive retinopathy,” “hypertensive choroidopathy”):
 - Severe (often associated with acute blindness)
 - Retinal detachment (complete or partial)
 - Hyphema
 - Retinal hemorrhages
 - Less severe (may only be obvious on ophthalmologic examination)
 - Papilledema
 - Vascular tortuosity and segmentalization
 - Periarterial intraretinal infiltrates
- Renal Effects:
 - Elevated intraglomerular pressure due to abnormal renovascular autoregulation (ineffective vasoconstriction of renal afferent arterioles) leads to glomerular damage (glomerulosclerosis and atrophy, proliferative glomerulitis) and results in protein loss in urine (proteinuria)
 - Proteinuria leads to tubular damage
 - tubular inflammation and atrophy
 - Interstitial fibrosis
- Central Nervous System Effects:
 - Damage may result from focal hemorrhage or from cerebral edema.
 - Intracranial abnormalities responsible for predominant signs (“hypertensive encephalopathy”)
 - Most common signs of hypertensive encephalopathy
 - Seizures (grand mal or focal facial)
 - Altered mentation: dementia, depression, stupor, coma
 - Isolated cranial nerve deficits
 - Nystagmus
 - Photophobia
- Cardiovascular Effects:
 - Left ventricular hypertrophy
 - Systolic heart murmur
 - Gallop rhythm
 - Sensitivity to fluids (i.e., “normal” amounts of fluid administration result in congestive heart failure)
 - Overt heart failure is rare unless fluids are administered.
 - Epistaxis



SIGNALMENT/HISTORY

- There are no known breed predilections for the development of systemic hypertension, but sighthounds (e.g., greyhounds, deerhounds) have normal blood pressure ranges that are higher than other breeds.
- There is no age predilection for development of systemic hypertension, but middle-aged to older animals are at increased risk for the systemic diseases likely to lead to systemic hypertension.

Risk Factors/Causes

- Some systemic illnesses have an increased probability of development of systemic hypertension as a complication.
- Dogs:
 - Acute or chronic renal diseases, especially those associated with proteinuria
 - Adrenal diseases
 - Hyperadrenocorticism
 - Hyperaldosteronism
 - Pheochromocytoma
 - Sex hormone abnormalities
 - Diabetes mellitus
 - Use of medications associated with increased blood pressure (e.g., phenylpropanolamine, corticosteroids)
- Cats:
 - Renal disease
 - Hyperthyroidism

Historical Findings

- Overt abnormalities that may be noted by owner:
 - Acute blindness, hyphema, retinal detachment
 - Depression
 - Photophobia
 - Epistaxis
 - Seizures
 - Evidence of underlying disease (e.g., polyuria, polydipsia etc.)
- Subtle abnormalities may be missed by owner:
 - Changes in behavior that may be attributed to aging
 - Hiding, depression
 - Subtle signs of underlying disease



CLINICAL FEATURES

- Evidence of target organ damage
 - Ocular changes (Figure 47.1):
 - Acute blindness
 - Retinal and choroidal changes as outlined previously
 - Renal changes:
 - Palpably small, irregular kidneys
 - Polyuria/polydipsia
 - Proteinuria
 - Neurologic changes:
 - Seizures
 - Changes in mentation
 - Focal cranial nerve deficits
 - Cardiovascular changes:
 - Systolic heart murmur, typically left sided
 - Gallop rhythm
 - Epistaxis
- Evidence of underlying (causative) disease may be detected.



■ **Figure 47.1** Ocular changes associated with hypertensive choroidopathy in a hypertensive cat. The hyper-reflective appearance of the right eye is consistent with retinal detachment. This cat is also showing a mild degree of photophobia.



DIFFERENTIAL DIAGNOSIS

- Ocular changes:
 - Retinal detachment due to infection or inflammation
 - Hyphema/retinal hemorrhage due to bleeding disorders
- Renal changes:
 - Acute or chronic renal disease of any cause
 - Infectious causes of proteinuria
- Neurologic changes:
 - Seizures
 - Epilepsy
 - Intracranial mass lesions (e.g., neoplasia, abscess)
 - Inflammatory brain lesions
 - Glucose or electrolyte abnormalities/toxins
 - Changes in mentation
 - Intracranial mass lesions
 - Cerebral edema due to infection/inflammation
 - Severe electrolyte abnormalities/toxins
 - Hypoglycemia
 - Focal cranial nerve deficits
 - Intracranial mass lesions
 - Inflammatory brain lesions
- Cardiovascular changes:
 - Heart murmur
 - Hypertrophic or dilated heart disease
 - Valvular disease
 - Gallop rhythm
 - Hypertrophic or dilated heart disease
 - Epistaxis
 - Nasal tumors, nasal infections
 - Bleeding disorders, including coagulopathies, thrombocytopenias, thrombocytopathias



DIAGNOSTICS

- Indications for blood pressure assessment for systemic hypertension include
 - Evidence of target organ damage as described previously
 - Evidence of systemic disease associated with development of systemic hypertension
- Random blood pressure measurement on young, healthy animals is discouraged due to increased possibility of false-positive readings (i.e., falsely elevated due to activity or excitement).

- Dogs:
 - Evidence of target organ damage
 - Ocular findings consistent with hypertensive choroidopathy, hypertensive retinopathy, or intraocular hemorrhage as outlined previously
 - Proteinuria without urinary tract infection
 - Intracranial neurologic signs, including depression or changes in mentation
 - Unexplained left ventricular hypertrophy
 - Epistaxis
 - Evidence of causative disease
 - Chronic or acute renal disease
 - Hyperadrenocorticism
 - Pheochromocytoma
 - Adrenal mass
 - Diabetes mellitus
- Cats:
 - The same for dogs as previously described in addition
 - Hyperthyroidism
 - Cats older than 10 years of age (due to high prevalence of renal disease and hyperthyroidism)
- Blood pressure measurement technique
 - Preparation
 - Blood pressure should be measured prior to other diagnostic activities (e.g., blood sampling, radiographs).
 - A period of acclimation (calming, preferably with only mild restraint) of at least 5 to 10 minutes is allowed prior to measurement.
 - Choose an indirect (Doppler or oscillometric) blood pressure cuff of a width that is ~40 percent of limb circumference.
 - Place cuff snugly at point of measurement (during measurement, limb or tail is positioned so that cuff is at the level of heart).
 - Tail head (cat or dog, Figure 47.2a)
 - Forelimb at level of radius (preferred site in cats, Figure 47.2b)
 - Hindlimb at metatarsal level (Figure 47.2c)
- Doppler sphygmomanometric blood pressure measurement (Figure 47.3)
 - Coupling gel is applied to Doppler crystal, which is then applied over the artery distal to the cuff. The sound generated by blood flow when the Doppler crystal is in the optimal position should be clear and crisp.
 - The cuff is inflated until the Doppler signal is silenced. The cuff is then slowly deflated until the Doppler signal is again heard. The pressure (mm Hg) at which the Doppler signal is again detected is recorded as the systolic pressure. After further deflation, the pressure at which the audible signal becomes muffled may be recorded as the diastolic pressure.
 - Systolic pressure is most reliably estimated by this method. Diastolic pressure can be difficult to determine accurately in many animals.
 - Five measurements should be taken and averaged for final value.



(a)



(b)

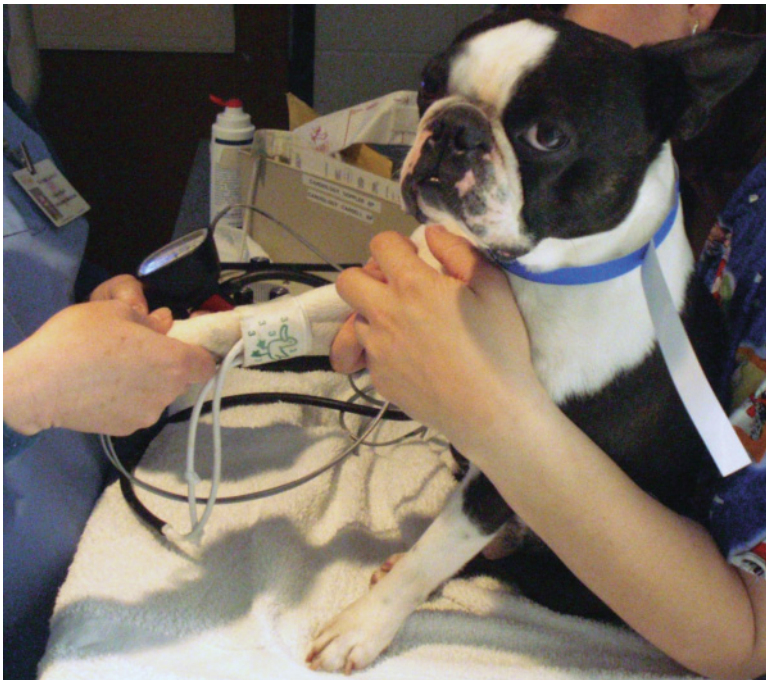
■ **Figure 47.2** (a) cuff at tailhead in a cat, (b) cuff at level of radius in a cat, and (c) cuff at metatarsal level in a dog.

- Oscillometric blood pressure measurement (Figure 47.4)
 - Automated inflation and deflation reduce operator error.
 - Oscillometric monitors deliver systolic, diastolic, and mean arterial pressures as well as heart rate.
 - Five measurements should be taken and averaged for final value.
- Assessment:
 - If clinical signs of target organ damage are present, therapy is warranted if systolic blood pressure >160 mmHg.



(c)

■ **Figure 47.2** *Continued*



■ **Figure 47.3** Doppler sphygmomanometric blood pressure measurement in a dog. The cuff is placed around the forelimb at the level of the radius and the leg is elevated to the level of the heart during readings.



■ **Figure 47.4** Oscillometric blood pressure measurement. The cuff is placed around the distal hindlimb at the level of the metatarsal arteries. The patient is resting comfortably with minimal restraint.

- If clinical signs of target organ damage are not present, the following guide may be used based on systolic blood pressure:
 - Systolic blood pressure <150 mmHg: no therapy required, monitor if possible causative disease is present
 - Systolic blood pressure 150 to 160 mmHg: if presence of underlying disease is confirmed, repeat blood pressure measurement at another session to confirm abnormality. If confirmed systolic blood pressure >150 mmHg, consider therapy.
 - Systolic blood pressure 160 to 180 mmHg: confirm with second measurement session and treat if underlying disease is present
 - Systolic blood pressure >180 mmHg: therapy for systemic hypertension is indicated if causative disease is present or strongly suspected



THERAPEUTICS

- Objectives of therapy
 - Immediate relief of clinical signs of target organ damage
 - Reduction of detected and undetected target organ damage

Drug(s) of Choice

- Acute systemic hypertension (clinical signs of target organ damage present)
 - Nitroprusside (intravenous)
 - Potent direct arterial dilator
 - Given as continuous rate infusion via an intravenous catheter with fluid pump
 - Continuous blood pressure monitoring (ideally, direct monitoring via indwelling arterial catheter) is recommended.
 - Dose (dogs only): 1 to 10 µg/kg per minute, start at lowest dose and titrate according to continuous blood pressure monitoring.

- Hydralazine (oral)
 - Potent direct arterial dilator
 - Onset of action after oral dosage: approximately 1 to 2 hours
 - Dose (dogs or cats): 0.05 to 4 mg/kg every 12 hours PO, start at lowest dose and titrate to effect.
- Chronic systemic hypertension
 - Underlying disease should be managed optimally (e.g., hyperadrenocorticism, hyperthyroidism).
 - Efficacy of chronic antihypertensive medications should be confirmed by repeat blood pressure measurement approximately 7 days after beginning medication or changing dosage.
 - Once blood pressure is controlled by chronic antihypertensive medication, blood pressure should be routine monitored approximately every 3 months.
- Dogs:
 - ACEIs
 - First-line drug for all systemic hypertension
 - Reduces proteinuria in affected dogs
 - ACEIs alone may control mild systemic hypertension adequately but are unlikely to control severe hypertension as monotherapy.
 - Dose:
 - Enalapril: 0.5 mg/kg every 12 hours PO
 - Benazepril: 0.25 to 0.5 mg/kg every 12 to 24 hours PO
 - Amlodipine besylate
 - Long-acting dihydropyridine calcium channel antagonist
 - Effective, especially in combination with ACEI
 - Dose: 0.1 to 0.4 mg/kg every 24 hours PO
 - Spironolactone
 - Aldosterone antagonist
 - May be helpful as *adjunctive* medication for control of hypertension
 - Dose: 1 to 2 mg/kg every 12 hours
- Cats:
 - Amlodipine besylate
 - Drug of choice for long term control of systemic hypertension in most cats
 - Well tolerated by most cats
 - Dose: 0.625 mg every 24 hours PO for cats up to 5 kg, 1.25 mg every 24 hours PO for cats >5 kg
 - ACEIs
 - Less effective as a single agent in cats than in dogs
 - May be used as adjunctive therapy, especially if proteinuria is present
 - Dose: same as dogs
 - Spironolactone
 - Aldosterone antagonist
 - May be helpful as *adjunctive* medication for control of hypertension
 - Dose: same as dogs

- β -blocking medications (propranolol, atenolol)
 - Atenolol most frequently used to limit heart rate in cats with hyperthyroidism
 - May be used as *adjunctive* therapy to control blood pressure
 - Dose: 6.25 to 12.5 mg per cat every 12 hours PO

Precautions/Interactions

Hypotension

- May occur if any medications are overdosed or if dehydration occurs in a patient receiving antihypertensive medications
- Clinical signs: collapse, weakness, tachycardia, prolonged capillary refill time, and prerenal azotemia
- Discontinue medication temporarily. Fluid support may be needed until the effects of the medication subside and dehydration is remedied.
- Close monitoring is required when giving direct arterial dilators.
- ACEIs may cause worsening of azotemia if administered to dehydrated animals.

Alternative Drugs

- At this time, no alternative medications or treatments have been proven effective in control of systemic hypertension in dogs and cats.

Diet

- Although moderate sodium reduction and weight control are likely generally beneficial in aging animals, no particular dietary manipulation has been proven to be effective in controlling systemic hypertension in dogs and cats.



COMMENTS

- Many disease associated with systemic hypertension can be controlled but not cured (e.g., renal disease, hyperadrenocorticism); antihypertensive medications in these patients are likely to be lifelong and may need upward adjustment over time.
- Some diseases (e.g., hyperthyroidism, pheochromocytoma) can be eliminated by appropriate therapy (medical or surgical). Systemic hypertension may resolve after treatment of underlying disease, but monitoring is required as blood pressure medications are slowly reduced. In the case of hyperthyroidism, systemic hypertension may become evident *after* therapy for the disease.
- Use of PPA may be associated with systemic hypertension. In dogs in which use of PPA is indicated, normal blood pressure should first be confirmed by a baseline measurement. If baseline blood pressure is within normal range, PPA can be initiated and blood pressure is rechecked approximately 1 to 2 weeks later. If blood pressure is normal while the patient is receiving PPA, PPA can be continued with blood pressure monitoring approximately every 3 months. If baseline or first recheck blood pressure is elevated, use of PPA should be avoided.

Client Education

- Control of systemic hypertension is most likely to be successful when blood pressure medications are giving consistently.
- Optimal treatment of underlying disease is needed in addition to antihypertensive medications to control systemic hypertension.
- Successful antihypertensive therapy frequently involves use of multiple medications and is often lifelong.

Patient Monitoring

- Blood pressure should be monitored continuously in patients with acute hypertension associated with target organ damage until blood pressure is controlled.
- Blood pressure should be assessed within 1 week of initiation or change in chronic therapy.
- Once a patient's blood pressure is stable and underlying disease is controlled, blood pressure should be monitored approximately every 3 months.

Expected Course and Prognosis

- Cause of death or euthanasia is typically related to the underlying disease rather than systemic hypertension, but poorly controlled systemic hypertension contributes to worsening of renal disease and may result in additional complications.

Abbreviations

- ACEI: angiotensin-converting enzyme inhibitor
- PO: by mouth
- PPA: phenylpropanolamine

Suggested Reading

- Brown, S, Atkins, C, Bagley, R, et al. Guidelines for the identification, evaluation, and management of systemic hypertension in dogs and cats. *J Vet Intern Med* 2007;21:542–558.
- Brown, SA, and Henik, RA. Diagnosis and treatment of systemic hypertension. *Vet Clin North Am Small Anim Pract* 1998;28:1481–1494.
- Elliott, J, Barber, PJ, Syme, HM, et al. Feline hypertension: clinical findings and response to antihypertensive treatment in 30 cases. *J Sm Anim Prac* 2001;42:122–129.
- Jacob, F, Polzin, DJ, Osborne, CA, et al. Association between initial systolic blood pressure and risk of developing a uremic crisis or of dying in dogs with chronic renal failure. *J Am Vet Med Assoc* 2003;222:322–329.
- Syme, HM, Barber, PJ, Markwell, PJ, et al. Prevalence of systolic hypertension in cats with chronic renal failure at initial evaluation. *J Am Vet Med Assoc* 2002;220:1799–1804.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Patti S. Snyder

Hypertrophic and Restrictive Cardiomyopathy



DEFINITION/OVERVIEW

- HCM is an idiopathic disease of the myocardium characterized by concentric hypertrophy and impaired diastolic relaxation. Concentric hypertrophy is a thickened ventricular wall with a normal to small chamber size, caused by a primary, inherent problem of the myocardium.
- RCM comprises a diverse group of myocardial conditions including endocardial, subendocardial, or myocardial fibrosis or other infiltrative disease that results in decreased ventricular compliance.



ETIOLOGY/PATHOPHYSIOLOGY

- Unknown; recent investigations have revealed a genetic origin of HCM in two breeds of cat, the Maine coon and Ragdoll.
- Concentric hypertrophy causes a noncompliant ventricle and leads to reduced diastolic filling and increased diastolic pressures. Diastolic dysfunction may result in atrial dilation with congestive heart failure, left atrial thrombi formation with systemic embolization, impaired myocardial perfusion, myocardial ischemia with subsequent arrhythmias, dynamic ventricular outflow obstruction, and end-stage myocardial failure.
- RCM is also characterized by abnormal diastolic function or a restriction of diastolic filling that results in many of the same pathophysiologic and hemodynamic consequences as HCM.

Systems Affected

- Cardiovascular—Impaired myocardial perfusion, myocardial ischemia with subsequent arrhythmias
- Respiratory—Tachypnea or cyanosis due to pulmonary edema or pleural effusion
- Musculoskeletal—Systemic embolization (pelvic limbs most common) resulting in paresis/paralysis and musculoskeletal pain



SIGNALMENT/HISTORY

Species

- HCM is the most common cardiac disease in cats and is very rare in dogs.

Gender

- More prevalent in males (up to 87 percent in some studies)

Age

- Most common in middle-aged cats (4–7 years), but has been reported in cats from 3 months to 17 years of age

Breed

- Domestic shorthair (most common), Maine coon, American shorthair, Persian, and Ragdoll

Historical Findings

- Many cats are asymptomatic.
- Tachypnea
- Inappetence
- Lethargy
- Syncope
- Lameness, paresis (pelvic limbs most common), or vocalization
- Sudden death



CLINICAL FEATURES

- Tachypnea
- Orthopnea
- Muffled respiratory or heart sounds with pleural effusion
- Crackles with pulmonary edema
- Heart murmur; variable intensity systolic murmur with point of maximal intensity in the parasternal region
- Gallop rhythm
- Premature beats
- Jugular pulsations or distention
- Poor body condition score
- Hindlimb paresis/paralysis with extreme pain, absent to weak femoral pulses, cyanosis of nail beds and footpads, and hypothermia with thromboembolic disease



DIFFERENTIAL DIAGNOSIS

- HCM is considered a primary disease of the myocardium and all other causes for concentric hypertrophy must be ruled out. Other causes for concentric hypertrophy include:
 - Systemic hypertension
 - Hyperthyroidism
 - Aortic stenosis
 - Acromegaly (rare in cats)



DIAGNOSTICS

Laboratory Tests

- Pleural or abdominal effusion cytology: Modified transudate is most common, but pure transudate or chylous effusion is also possible.
- Thromboembolic disease: Elevations in creatine kinase, enzymes of hepatocellular damage (i.e., ALT, AST), renal values (i.e., BUN, creatinine), potassium, and cardiac troponin I; lactate obtained from vein in affected limb(s) is often higher than lactate concentration in nonaffected limb(s).

Electrocardiography

- Highly variable and nonspecific
- Left axis deviation (partial left bundle branch block)
- Ventricular or atrial premature complexes or tachyarrhythmias

Thoracic Radiography

- Mild to moderate generalized cardiomegaly (Figure 48.1)
- Left atrial or biatrial enlargement (Figure 48.2)
- Interstitial or alveolar infiltrates consistent with pulmonary edema
- Pleural effusion
- Pulmonary vascular distension

Echocardiography

- Gold standard for antemortem diagnosis
- M-mode and two-dimensional echocardiography:
 - HCM
 - Left ventricular wall thickness at end-diastole >5.5 mm
 - Papillary muscle hypertrophy
 - SAM of the mitral valve is present in approximately 50 percent of cases.



■ **Figure 48.1** Lateral thoracic radiograph of a cat with generalized cardiomegaly and pulmonary edema secondary to hypertrophic cardiomyopathy.



■ **Figure 48.2** Dorsoventral thoracic radiograph of biatrial enlargement of a cat with severe hypertrophic cardiomyopathy. This is a classic "valentine-shaped" heart sometimes seen with this disease.

- Left atrial enlargement with advanced disease (left atrial to aortic diameter >1.5)
- RCM
 - Variable echocardiographic findings in RCM
 - Severe left atrial dilation is a common feature.
 - Left ventricular internal dimensions are typically mildly to moderately reduced.
 - May demonstrate loss of normal left ventricular symmetry, distorted or fused papillary muscles, and mild left

Pathology

Hypertrophic Cardiomyopathy

- Thickening of the left ventricular myocardium (the interventricular septum and free wall), with the entire wall commonly being 8- to 11-mm thick
- Papillary muscle hypertrophy
- Smaller than normal left ventricular chamber

Restrictive Cardiomyopathy

- Patchy or diffuse endocardial, subendocardial, or myocardial deposition of fibrous tissue
- The endocardium may appear whitish-gray, opaque, and thickened.



THERAPEUTICS

Acute Congestive Heart Failure

- Oxygen supplementation
- Furosemide: 1 to 4 mg/kg IV or IM every 1 to 2 hours initially and then adjusted as tachypnea resolves (usually 1–2 mg/kg every 6–12 hours); must be used with caution in patients with concurrent renal disease; hypokalemia can occur as a secondary complication of furosemide therapy
- Serial renal values and electrolytes
- Thoracentesis as needed to control pleural effusion

Acute Thromboembolic Crisis

- Treatment of congestive heart failure
- Analgesia: Use one of the following medications:
 - Hydromorphone: 0.05 to 0.1 mg/kg IV, IM, or SQ every 2 to 6 hours
 - Morphine: 0.05 to 0.2 mg/kg IM or SQ every 4 to 6 hours
 - Buprenorphine: 0.01 to 0.03 mg/kg IV, IM, or buccally every 6 to 8 hours
 - Fentanyl (2 μ g/kg IV, then 3–5 μ g/kg per hour IV CRI)

Anticoagulant Therapy

- Efficacy is unknown in cats.
- Additional studies are necessary to establish dosage and frequency.
 - Unfractionated heparin: 250 U/kg SQ every 8 hours, aPTT should be prolonged by one-and-a-half to two times normal.
 - Low-molecular-weight heparins:
 - Enoxaparin: 1 mg/kg SQ every 12 hours
 - Dalteparin: 100 U/kg SQ every 24 hours
 - Aspirin: 5 to 81 mg PO every 72 hours
 - Clopidogrel: 18.75 mg PO every 24 hours

Thrombolytic Therapy

- Tissue plasminogen activator or streptokinase: very expensive, severe or fatal complications including reperfusion injury or hemorrhage, no survival benefit compared to conservative therapy

Chronic Congestive Heart Failure

Diuretics

- Furosemide: 0.5 to 2.0 mg/kg PO every 8 to 48 hours
- Hydrochlorothiazide: 1 to 2 mg/kg PO every 12 to 24 hours, typically used with furosemide in patients refractory to furosemide monotherapy
- Spironolactone: 1 to 2 mg/kg PO every 12 to 24 hours, typically used with furosemide

Angiotensin-Converting Enzyme Inhibitors

- Use only one.
- Benazepril: 0.25 to 0.05 mg/kg PO every 24 hours
- Enalapril: 0.25 to 0.5 mg/kg PO every 12 to 24 hours

Thromboprophylaxis

Recommended in patients after thromboembolic events and for those patients at risk for systemic emboli

- Aspirin 5 to 81 mg PO every 72 hours
- Clopidogrel: 18.75 mg PO every 24 hours
- β -blockers: never been shown to improve patient outcome, use extreme caution in patients with congestive heart failure, systolic dysfunction, hypotension, or bradyarrhythmias; may be preferred drug choice with systolic anterior motion of mitral valve
- Atenolol: 6.25 to 12.5 mg PO every 12 to 24 hours, slowly titrated to achieve a heart rate 140 to 160

- Calcium channel blockers: never been shown to improve patient outcome, use extreme caution in patients with congestive heart failure, systolic dysfunction, hypotension, or bradyarrhythmias
- Diltiazem: 7.5 mg PO every 8 to 12 hours



COMMENTS

Patient Monitoring

- Asymptomatic patients should have echocardiography every 6 to 12 months.
- Patients receiving diuretics should be monitored for azotemia and electrolyte abnormalities (e.g., hyponatremia, hypokalemia).
- After a thromboembolic event, assess for return of limb function, reperfusion injury (e.g., hyperkalemia), limb necrosis, or self-mutilation.

Prognosis

- The prognosis for HCM and RCM is generally based on clinical presentation, echocardiographic and radiographic evidence of elevated diastolic pressures, and response to therapy. Asymptomatic cats with mild left atrial enlargement are believed to have a good long-term prognosis. Asymptomatic cats with marked left atrial enlargement are at risk for developing heart failure. Cats that present in heart failure have a poor prognosis with a short survival time (weeks to months). Cats that present in heart failure and respond favorably to therapy may do well for longer periods. Cats presenting with aortic thromboembolism have a poor prognosis.

Abbreviations

- ALT: alanine aminotransferase
- AST: aspartate aminotransferase
- aPTT: activated partial thromboplastin time
- BUN: blood urea nitrogen
- CRI: constant rate infusion
- HCM: hypertrophic cardiomyopathy
- IM: intramuscularly
- IV: intravenously
- PO: by mouth
- RCM: restrictive cardiomyopathy
- SAM: systolic anterior motion
- SQ: subcutaneously

Suggested Reading

Arndt, JW, and Oyama, MA. Feline hypertrophic cardiomyopathy. *Stand Care* 2008;10.4:1–10.

Baty, CJ. Feline hypertrophic cardiomyopathy: an update. *Vet Clin North Am Small Anim Pract* 2004;34:1227–1234.

Fox, PR. Feline cardiomyopathies. In: Fox, PR, Sisson, D, and Moise, NS, eds. *Textbook of Canine and Feline Cardiology*, pp. 896–923. Philadelphia: WB Saunders Co, 1999.

Kittleson, MD, and Kienle, RD. *Small Animal Cardiovascular Medicine*, pp. 347–396. St. Louis: Elsevier Health, 1998.

Rodriguez, DB, and Harpster, NH. Feline hypertrophic cardiomyopathy: etiology, pathophysiology, and clinical features. *Compend Contin Educ Pract Vet* 2002;24:364–373.

Author: Shannon Jordan

Acknowledgment to authors of component in original in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Bruce W. Keene and Francis W.K. Smith

Hyphema



DEFINITION/OVERVIEW

- Hyphema is the presence of blood in the anterior chamber.



ETIOLOGY/PATHOPHYSIOLOGY

- Trauma, either blunt or penetrating, is most common cause.
- Bleeding or clotting disorders (e.g., thrombocytopenia, inherited clotting deficiencies, consumption of clotting factors, liver failure)
- Blood dyscrasias (e.g., polycythemia, hyperviscosity)
- Systemic hypertension
- Uveitis, especially with concurrent vasculitis (e.g., FIP in cats, rickettsial diseases in dogs)
- Other ocular disease (e.g., neoplasia, retinal detachment, chronic glaucoma, collie eye anomaly, persistent primary hyperplastic vitreous) generally due to stimulation of vascular growth on iris (preiridal fibrovascular membrane)

Systems Affected

- Ophthalmic



SIGNALMENT/HISTORY

- Hyphema can occur in any dog or cat regardless of age, breed, or sex.
- Because there are many causes for hyphema, the signalment and history of the patient will vary and should be used as a tool to guide the clinician towards a diagnostic plan.

Historical Findings

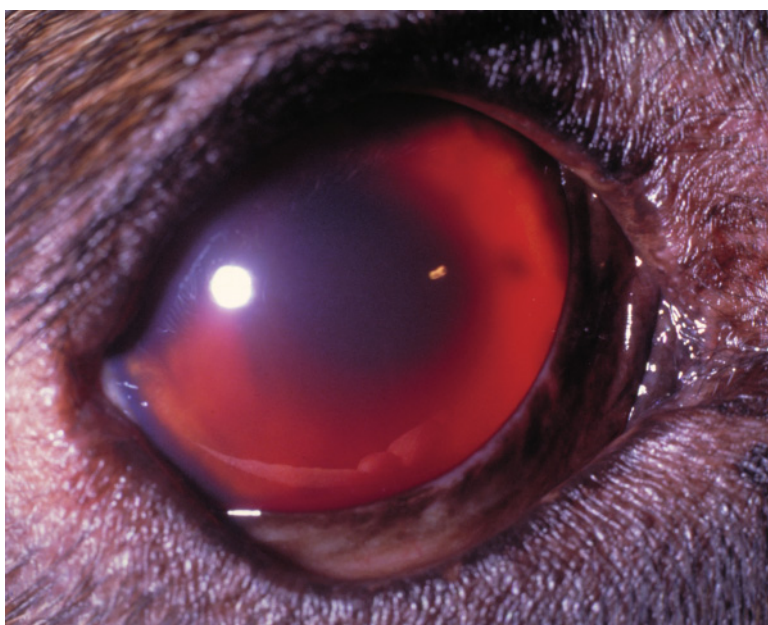
- Many dogs and cats with hyphema will present as an ocular emergency when the owners notice blood in the eye.

- If hyphema is caused by trauma the patient may be presented for signs of acute ocular pain (e.g., epiphora and blepharospasm).
- Weight loss, lethargy, or decreased appetite may indicate a systemic cause.

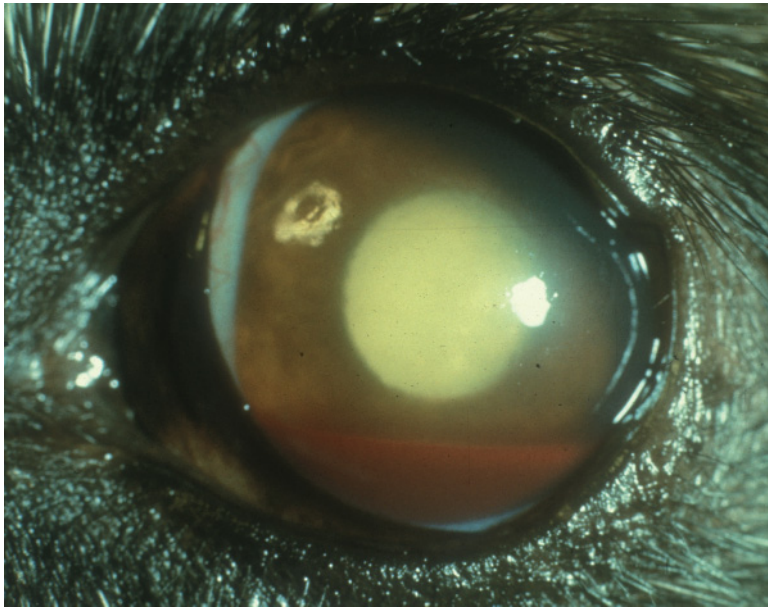


CLINICAL FEATURES

- The clinical features of hyphema will depend on the quantity of blood, whether or not the blood is clotted, the duration of the hyphema, and potentially the activity of the animal.
- Acute, traumatic hemorrhage will appear bright red (Figure 49.1).
- If the blood partially fills the anterior chamber and the animal has been inactive for some time, the blood will settle out in a gravity dependent manner (Figure 49.2).
- Hemorrhage that completely fills the anterior chamber will generally clot within a few days and turn dark in color (Figure 49.3, “eight ball” hemorrhage).
- Hyphema associated with infectious disease, such as FIP, will often be mixed with inflammatory cells in a fibrin clot. Clots will often localize over the pupil.
- Blood in the anterior chamber may or may not clot. The reasons for this are not well understood.
- Intraocular pressure may be elevated.



■ **Figure 49.1** Acute hyphema—blood is dispersed throughout the anterior chamber. The ability to see internal structures indicates the hemorrhage is not extensive.



■ **Figure 49.2** Blood has settled out into the ventral anterior chamber. The amount of blood is less than one-third the volume of the anterior chamber and carries a good prognosis for complete resolution.



■ **Figure 49.3** “Eight ball” hemorrhage in a proptosed globe. The anterior chamber is completely filled with blood. The prognosis for vision in this eye is grave. Hyphema this extensive generally leads to glaucoma or phthisis bulbi.



DIFFERENTIAL DIAGNOSIS

- Iris injection/vascularization
- Corneal vascularization or intrastromal corneal hemorrhage



DIAGNOSTICS

- Hyphema is diagnosed by observing blood in the anterior chamber.
- Thorough and detailed history, physical and ophthalmic examinations (including opposite eye) should be done to rule in/out trauma.
- Ophthalmic examination should always include fluorescein staining for corneal ulcers and intraocular pressure measurement for secondary glaucoma.
- Other diagnostic tests should be geared toward the suspected cause of hyphema.
 - Minimum data base (i.e., CBC, serum chemistries, urinalysis) for all suspected systemic causes.
 - Coagulopathy—Tests to assess hemostasis
 - Metastatic neoplasia—Thoracic radiographs and abdominal ultrasound
 - Serum titers for suspected infectious disease
- Ocular ultrasound is indicated when blood prevents complete examination of the eye, to identify neoplasia, retinal detachment and posterior segment (vitreal, subretinal) hemorrhage.

Pathological Findings

- Blood (free or in proteinaceous matrix) is seen in the anterior chamber, iridocorneal angle, and trabecular meshwork.
- Blood or fibrinous adhesions (anterior synechiae) may mechanically occlude the iridocorneal angle and cause secondary glaucoma.
- Minor to extensive posterior synechiae may be present.
- Blood staining of the cornea may result with concurrent glaucoma.
- Fibrovascular membrane over the iris surface is common when hyphema is secondary to chronic ocular disease.



THERAPEUTICS

- The immediate objectives in the treatment of hyphema are:
 - Keep the animal quiet to prevent rebleeding (especially when secondary to trauma).
 - Treat concurrent anterior uveitis.
 - Eliminate or manage underlying cause when identified.
 - Prevent or treat secondary glaucoma.

Drug(s) of Choice

- Topical 1% prednisolone drops or 0.1% dexamethasone ointment every 6 to 8 hours for concurrent anterior uveitis.
- Topical 1% atropine sulfate drops or ointment every 8 hours until the pupil dilates, then use to effect. Atropine is used to prevent posterior synechia, pupil obstruction and iris bombé.
- Topical 2% dorzolamide drops every 8 hours to decrease aqueous humor formation if intraocular pressure is elevated.
- tPA 25 µg injected into the anterior chamber to dissolve formed clots.
 - tPA frequently causes rebleeding and should not be used in the presence of active hemorrhage or nonclotted blood.

Precautions/Interactions

- The use of topical or systemic nonsteroidal anti-inflammatory agents is not recommended due to their effect on platelet function.
- Topical glucocorticoids should not be used in the presence of corneal ulceration.
- Topical ointment preparations should not be used if the eye has been perforated.
- Continuous dilation of the pupil with atropine may obstruct aqueous humor outflow through the iridocorneal angle.
- Close monitoring of the intraocular pressure is recommended when using atropine.
- If intraocular pressure is elevated, atropine is contraindicated unless pressure elevation is caused by iris bombé.

Activity

- The activity of the patient should be restricted for several days after hyphema has occurred. Cage rest or sedation may be necessary.

Surgical Considerations

- Surgery is rarely indicated or performed to treat hyphema.
- Uncontrolled glaucoma and complete hyphema that has been present for 5 to 10 days can be an indication for invasive surgery to remove the blood clot. Surgery often results in rebleeding.
- Uncontrolled glaucoma and complete hyphema carry a poor prognosis for glaucoma control or vision, enucleation may be required to relieve pain.



COMMENTS

Client Education

- Hyphema often obstructs vision and increases the risk of further injury to the eye.
- Glaucoma if not already present could develop, especially with moderate to severe hyphema.

- Owner should contact veterinarian if signs of pain occur or worsen (i.e., squinting, tearing, rubbing, lethargy) because this could indicate glaucoma or corneal ulceration.
- If pupil is widely dilated, discontinue atropine until pupil begins to constrict again.
- Emphasize the necessity of treating the underlying cause of hyphema.

Patient Monitoring

- Monitor underlying disease as recommended.
- Monitor eyes with moderate to severe hyphema frequently.
 - If IOP elevated, recheck daily, additional ocular hypotensive medications may be necessary.
 - If IOP in normal range, monitor IOP every 2 to 3 days.
- Eyes with hyphema <40 percent of anterior chamber should be monitored every 2 to 3 days until resolved.

Possible Complications

- Chronic glaucoma and pain
- Blindness
- Phthisis bulbi
- Cataract

Expected Course and Prognosis

- Mild hyphema (<30 percent of anterior chamber filled when blood settles) carries a good prognosis for vision.
- Moderate hyphema (30–50 percent of anterior chamber filled when blood settles) carries a guarded prognosis for vision due to potential of secondary glaucoma.
- Severe hyphema (>50% of anterior chamber filled when blood settles) carries a poor prognosis for vision due to intraocular changes and uncontrollable secondary glaucoma.

Abbreviations

- CBC: complete blood count
- FIP: feline infectious peritonitis
- IOP: intraocular pressure
- tPA: tissue plasminogen activator

Suggested Reading

Maggs, DK, Miller, PE, and Ofri, R. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed., pp. 223–224. Philadelphia: Saunders Elsevier, 2008.

Martin, CL. *Ophthalmic Disease in Veterinary Medicine*, pp. 309–310. London: Manson Publishing, 2005.

- Peiffer, R, Wilcock, B, and Yin, H. The pathogenesis and significance of pre-iridal fibrovascular membrane in domestic animals. *Vet Path* 1990;27:41–45.
- Spoor, T, Hamnmer, M, and Belloso, H. Traumatic hyphema: failure of steroids to alter its course: a double-blind prospective study. *Arch Ophthalmol* 1980;98:116–119.
- Willis, MA. Ocular hypotensive drugs. *Vet Clin North Am Small Anim Pract* 2004;34:755–776.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Mark P. Nasisse

Hypotension



DEFINITION/OVERVIEW

- Hypotension is an abnormally low arterial blood pressure, often defined as a mean arterial pressure below 60 mmHg or systolic arterial pressure below 90 mmHg.



ETIOLOGY/PATHOPHYSIOLOGY

- Both cardiac output (volume of blood pumped by the heart per minute) and the vascular tone, or degree of systemic vascular resistance, contribute to arterial blood pressure. A dysfunction of either cardiac output or vascular tone or both can result in hypotension.
- Cardiac output is characterized by lack of venous return (amount of blood returning to the heart), decreased contractility (strength of myocardial contraction), and afterload (the pressure against which the heart must pump). A decrease in venous return or contractility or an increase in afterload will all decrease cardiac output, and potentially lead to hypotension. Anything that causes vasodilation (endotoxemia, hypercarbia, anesthetic gases, etc.) can decrease vascular tone and lead to hypotension.
- Hypotension occurs in 22 to 32 percent of anesthetized dogs and 33 percent of anesthetized cats. The incidence of hypotension in traumatized or sick awake dogs is unknown, but would be expected to be high due to blood loss, sepsis, and related conditions.

Systems Affected

- Nervous—decreased cognitive function, and leads to an obtunded or comatose patient
- Gastrointestinal—gastric and intestinal ischemia and subsequent mucosal sloughing
- Musculoskeletal—generalized weakness
- Hepatobiliary—hepatic ischemia which can decrease metabolism of drugs or clearance of toxins
- Cardiovascular—ischemia, arrhythmias, decreased contractility
- Renal/Urologic—renal tubular necrosis and acute renal failure



SIGNALMENT/HISTORY

- There are no breed or sex predilections for hypotension.
- Any age patient can develop hypotension, although older animals may be likely to develop hypotension.
- There is no genetic basis for hypotension.
- Signs associated with hypotension include depression, lethargy, weakness, pale mucous membranes, cool peripheral extremities, tachy- or bradycardia, and a slow capillary refill time.

Risk Factors/Causes

- Anesthesia
- Trauma
- Inflammation
- Sepsis
- Myocardial disease/failure
- Hemorrhage
- Vomiting
- Diarrhea

Historical Findings

- Depression
- Lethargy
- Weakness
- Disappearance from home
- History of trauma/blood loss
- Exercise intolerance
- History of vomiting or diarrhea



CLINICAL FEATURES

- Depression
- Lethargy
- Weakness
- Slow capillary refill time
- Pulse quality may or may not be poor
- Blanched skin/mucous membranes
- Cool peripheral extremities



DIFFERENTIAL DIAGNOSIS

- Sepsis—Septic patients are often, but not always, hypotensive. Septic patients will tend to have an inflammatory leukogram and be hypoglycemic, hypoproteinemic, and have other clinical signs (i.e., vomiting, infectious nidus, etc.).
- Hypovolemia—Patients who are severely dehydrated or have had blood loss may also be hypotensive. Hypovolemic patients rapidly respond to appropriate fluid therapy.
- Cardiac failure—Patients with myocardial disease who have compromised contractility may be hypotensive. Any patient with no obvious cause for hypotension should have a thoracic examination, including auscultation, radiographs, and echocardiography to rule out cardiac failure as a cause of hypotension.
- Arrhythmia—Patients with third-degree atrioventricular block or other causes of bradycardia may suffer collapse and weakness due to inability of the heart to maintain cardiac output. The blood pressure in these patients is often normal. An ECG should be checked if the patient is bradycardic.
- Electrolyte disturbances—Acidemia, hypocalcemia, hypokalemia, and hypomagnesemia may all complicate existing hypotension and should be ruled out by running an electrolyte and acid-base profile.
- Anemia—Patients who are anemic without being hypovolemic may present in a similar condition to hypotensive patients. A complete physical examination, blood count, biochemistry profile, and evaluation for autoimmune disease should be conducted in cases of suspected anemia. Patients with anemia without blood loss will tend to have a normal-to-high protein level and will have no identifiable source of blood loss (i.e., internal hemorrhage into the chest or abdomen or external hemorrhage).
- Neurologic disorder—Patients presenting obtunded or depressed should be given a thorough neurologic examination to rule out presence of neurologic disease. Patients with neurologic disease but without hypotension should have a normal blood pressure on evaluation.
- Hypoxemia—Patients with respiratory or cardiac illness who have impaired diffusion of oxygen in the lungs may resemble patients who are hypotensive in being depressed, weak, and may have pale or blue mucous membranes. Patients who are hypoxemic are usually normo-to-hypertensive unless a concurrent disease is present. Patients who are hypoxemic can be diagnosed on the basis of respiratory distress, an abnormally low pulse oximeter reading, or on an arterial blood gas analysis.



DIAGNOSTICS

- Indication: any patient presenting after trauma or with signs of depression, sepsis, lethargy, or any patient under anesthesia
- Doppler method—indirect method using a sphygmomanometer, blood pressure cuff, and Doppler sound device which gives systolic arterial pressure only

- Automated cuff—indirect method using a circumferential cuff which automatically inflates and deflates on a periodic basis, giving systolic, diastolic, and mean arterial pressure
- Transducer—direct method utilizing an arterial catheter and pressure transducer to give the gold standard real-time reading of systolic, diastolic, and mean arterial pressure

Pathological Findings

- Prolonged hypotension will cause ischemia, which can manifest in any organ. Ischemia will cause necrosis, and the brain, heart, and kidneys tend to be the most sensitive organs.



THERAPEUTICS

- The objective of treatment is to raise mean arterial blood pressure above 60 mm Hg and diastolic blood pressure above 40 mm Hg, or if no means to measure mean blood pressure are available, systolic arterial blood pressure above 90 mm Hg.

Drug(s) of Choice

- Crystalloid fluids: Balanced isotonic crystalloid fluid such as lactated Ringer's, Normosol-R, Plasmalyte 60 mL/kg
- Dobutamine 5 to 10 $\mu\text{g/kg}$ per minute IV CRI
- Dopamine 5 to 20 $\mu\text{g/kg}$ per minute IV CRI
- Ephedrine 60 $\mu\text{g/kg}$ IV

Precautions/Interactions

- Any drug that has the potential to cause or worsen hypotension should be used cautiously or not at all in patients who are already experiencing hypotension. This includes most anesthetic agents, some antibiotics if given rapidly, and drugs that cause vasodilation (nitroglycerine, nitroprusside, ACE inhibitors).

Alternative Drugs

- Phenylephrine 1 to 3 $\mu\text{g/kg}$ per minute CRI
- Norepinephrine 0.05 to 3 $\mu\text{g/kg}$ per minute CRI
- Vasopressin 0.5 to 5 mU/kg per minute CRI
- Epinephrine 0.01 to 0.1 $\mu\text{g/kg}$ per minute CRI

Activity

- Patients typically will be too weak to be active. Because many of the medications require continuous intravenous access, limiting patient movement while in a treatment cage may be helpful.

Surgical Considerations

- Anesthesia should generally be avoided in patients who have existing hypotension, or the hypotension should be resolved before anesthesia. If surgery is necessary to correct the underlying cause of hypotension (i.e., septic abdomen), the patient should be stabilized and blood-pressure-sparing anesthetic agents such as benzodiazepines (e.g., diazepam), opioids (e.g., hydromorphone, fentanyl, morphine), and dissociatives (e.g., ketamine) should be used. Etomidate is a very cardiovascularly friendly induction agent that can be combined with a benzodiazepine for rapid anesthetic induction. Use of etomidate alone can cause clonus. Etomidate (0.5–1 mg/kg IV) also can depress the hypothalamic-pituitary-adrenal axis, so administration of physiologic doses of glucocorticosteroids should be administered at the time of induction and again 24 hours later when etomidate has been used.



COMMENTS

- Blood flow is determined in part by blood pressure and is the true variable of interest in hypotension. Drugs that increase vascular tone (e.g., phenylephrine, ephedrine, epinephrine) will increase blood pressure, but this may be at the cost of peripheral blood flow and perfusion. These drugs should be used cautiously to improve blood pressure in hypotension.

Client Education

- A patient with hypotension should not be discharged.

Patient Monitoring

- Blood pressure should be monitored at least every 5 minutes during anesthesia or in emergent situations. For long-term treatment, blood pressure should be checked every 15 minutes for the first hour, then hourly thereafter if the patient is critical or every 6 hours once the patient is stable.

Possible Complications

- Possible clinical sequelae to hypotension include cerebral damage (especially blindness) and renal damage. These are typically noted before discharge. The owners should be informed that they should have regular bloodwork to ensure that the animal does not develop early onset chronic renal failure due to the hypotensive episode(s).

Expected Course and Prognosis

- Hypotension typically resolves rapidly with definitive treatment (such as fluids in a hypovolemic patient) and usually responds immediately to the drug treatments previously described.

- Most patients that develop mild hypotension under anesthesia suffer no long-term consequences.
- Severe hypotension can cause cerebral and renal damage.
- In some cases, particularly severe sepsis, patients may not respond to initial drug treatments and more aggressive medications (given in alternative treatments) will be necessary.
- Patients can respond to medication initially and then gradually redevelop hypotension. In nonresponder cases, it is important to rule out and treat complicating conditions (e.g., acidosis, hypocalcemia, anemia). In patients who do *not* respond to initial medication measures or develop recurring hypotension despite treatment, the prognosis is poor to grave.

Synonyms

- Shock, hypoperfusion, low blood pressure

Abbreviations

- ACE: angiotensin-converting enzyme
- CRI: constant rate infusion
- ECG: electrocardiogram
- IV: intravenously

Suggested Reading

deLaforcade, AM, and Rozanski, EA. Central venous pressure and arterial blood pressure measurements. *Vet Clin North Am Small Anim Pract* 2001;31(6):1163–1174.

DiBartola, SP. *Fluid Therapy in Small Animal Practice*, 2nd ed., pp. 428–450. Philadelphia: WB Saunders Co., 2000.

Hall, LW, Clarke, KW, and Trim, CM. *Veterinary Anaesthesia*, 10th ed., 39–44. Philadelphia: WB Saunders Co., 2000.

Wagner, AE, Wright, BD, and Hellyer, PW. Myths and misconceptions in small animal anesthesia. *J Am Vet Med Assoc* 2003;223(10):1426–1432.

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Hypothermia



DEFINITION/OVERVIEW

- Defined as a decrease in normal body temperature (37.8–39.2° C or 100.0–102.5° F) to below 37° C (99° F)
 - Mild hypothermia: 32 to 37° C (90–99° F)
 - Moderate hypothermia: 28 to 32° C (82–90° F)
 - Severe hypothermia: below 28° C (82° F)



ETIOLOGY/PATHOPHYSIOLOGY

- Under normal circumstances, the body produces heat as a byproduct of metabolic processes. Body heat is centered around the core, and by the process of thermoregulation, heat can be dissipated from the skin and respiratory tract. Activation of the autonomic nervous system and thermoregulatory in the hypothalamus occurs in response to cold and body cooling, and causes shivering and increased cellular metabolism in an attempt to produce heat and rewarm the body.
- Even during some stages of mild hypothermia, when the body temperature drops to below 93° F, adverse consequences such as peripheral vasodilation, decreased cellular metabolism, and decreased heat production occur. As hypothermia progresses to below 88°F (31° C) then animal can no longer thermoregulate.

Systems Affected

- Hepatic—decreased hepatic enzyme activity
- Renal/Urologic—increased glomerular filtration rate and diuresis, decreased sensitivity to antidiuretic hormone, fluid loss/dehydration; decreased renal blood flow, renal hypoxia, renal tubular necrosis
- Coagulation—coagulopathies including decreased platelet aggregation, decreased thromboxane A2 and decreased coagulation factor activity. Predisposition to DIC due to sequestration of platelets in the reticuloendothelial system in the liver and spleen.
- Cardiovascular—mild tachycardia with mild hypothermia, vasoconstriction can increase systemic vascular resistance, decreased tissue perfusion and cellular

hypoxia. Decreased response to catecholamines, bradycardia, decreased cardiac output, and hypotension. Atrial and ventricular fibrillation can occur with severe hypothermia.

- Respiratory—decreased tidal volume and respiratory rate, decreased minute ventilation, hypoxia
- Neurologic—decreased cerebral perfusion and oxygen delivery. Neurologic abnormalities can range in severity from depression and weakness to stupor or coma.
- Immune system—decreased immune function secondary to decreased neutrophil activation, phagocytic capacity, chemotaxis; decreased cytokine, and antibody production. Can lead to increased risk of infection and delayed wound healing
- Metabolic—decreased off-loading of oxygen in peripheral tissues due to left-shift of the oxyhemoglobin dissociation curve

Incidence/Prevalence

- Unknown, most common cause is peri-anesthetic hypothermia

Geographic Distribution

- None, although may be more common in cold wet environments



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predilection

- No breed predilection, although short haired, smaller breeds are at higher risk than large breeds

Mean Age and Range

- Neonatal animals and geriatric animals are at higher risk.

Predominant Sex

- None

Historical Findings

- Prolonged exposure to cold wet environments or submersion in cold water
- Unknown history if animal has wandered from home or may have experienced trauma
- History of anesthesia
- Unresponsive, cold animal

Physical Examination Findings

- Severity is dependent on degree and duration of hypothermia:
 - Mental depression
 - Lethargy
 - Weakness
 - Shivering
 - Muscle stiffness
 - Bradycardia
 - Hypotension
 - Decreased respiratory rate and depth
 - Stupor
 - Obtundation
 - Coma
 - Muffled to absent heart sounds
 - Bradycardia
 - Fixed dilated pupils
 - Death

Risk Factors/Causes

- Large body surface area to mass ratio in small animals
- Decreased heat production in neonatal or cachectic animals
- Prolonged preoperative preparation time
- Intraoperative or peri-anesthetic hypothermia and inadequate warming
- General anesthesia (worsens with duration of anesthesia)
- Inadequate shelter in cold or wet climates
- Inadequate food and water in cold or wet climates
- Hypothyroidism
- Cold or moist ambient environments
- Decreased thermoregulatory ability
- Impaired ability to seek out heat/shelter or leave cold environment (nonambulatory, debilitated, or injured animals)
- Decreased ability to generate heat (hypothyroid, neonatal, geriatric animals)



DIFFERENTIAL DIAGNOSIS

Diagnosis

- In animals with severe hypothermia, it may be very difficult to differentiate between death and hypothermia until aggressive rewarming measures have been instituted.

Differentiating Causes

- Must differentiate between other causes of neurologic depression, including trauma, hypovolemic or cardiogenic or septic shock, hepatic encephalopathy, toxin, neoplasia, hypoglycemia or other metabolic disorders



DIAGNOSTICS

Complete Blood Count/Chemistry/Urinalysis

- Usually normal
- Some patients may exhibit hyperglycemia and mild hemoconcentration.

Other Laboratory Tests

- Coagulation tests—thrombocytopenia, prolonged ACT, aPTT, and PT
- Endocrine—Decreased T4 with concomitant elevation in eTSH may reveal true hypothyroidism versus euthyroid sick syndrome associated with other underlying illnesses.

Diagnostic Procedures

- Temperature probes (esophageal or rectal) are useful in assessing patient's temperature and rewarming.

Electrocardiography

- Sinus bradycardia with prolonged PR, QRS, and RT intervals.
 - May see atrial fibrillation
 - Ventricular dysrhythmias is common.
 - Premature ventricular contractions, ventricular tachycardia, and ventricular fibrillation may be observed as hypothermia becomes progressively worse.



THERAPEUTICS

- In-patient therapy is recommended until temperature, acid-base and electrolyte status, and correction of underlying cause of hypothermia have been resolved.
- Body temperature may initially decrease further during early stages of rewarming due to improved circulation of the peripheral tissues, vasodilation, and mixing of blood from the core to the cooler periphery.
- Goal is to provide ambient rewarming measures without promoting further loss of heat.
- Oxygen supplementation and endotracheal intubation are both necessary in obtunded patients. In most severe cases, mechanical ventilation may be necessary.

- Passive rewarming with insulated blankets
- Active rewarming with external heat sources such as forced warm air blankets or circulating warm water blankets or pads
- Plastic bubble wrap or cellophane on limbs to prevent heat loss from feet, particularly during anesthetic procedures
- Core rewarming techniques such as warm peritoneal, gastric, or urinary lavage; warm water enemas, warm intravenous fluids, and warmed airway air

Drug(s) of Choice

- Oxygen supplementation: 50 to 150ml/kg per minute
- Isotonic crystalloid fluids

Contraindications

- Avoid lactated Ringer's solution with severe hypothermia because lactate requires hepatic metabolism.



COMMENTS

Patient Monitoring

- Monitor core body temperature very closely during rewarming.
- Monitor ECG and blood pressure.
- Frostbite

Prevention/Avoidance

- Avoid prolonged exposure to cold temperatures.
- Use warm water blankets or forced warm air blankets during anesthetic procedures.

Possible Complications

- Increased metabolic rate and shivering
- Increased cellular oxygen demand
- Thermal burns from inappropriate rewarming measures such as heating pads
- After drop phenomenon: core temperature of patient continues to fall during rewarming (passive and active)
- Rewarming shock: rapid vasodilation during rewarming that results in severe venous pooling; ideally, avoid warming body temperature more than 1° F per hour
- Frostbite
- Cardiac arrest
- Death

Expected Course and Prognosis

- Varies depending on degree and duration of hypothermia
- Worse prognosis with debilitated animals

Age-Related Factors

- Neonatal and geriatric patients are at higher risk.

Abbreviations

- ACT: activated clotted time
- aPTT: activated partial thromboplastin time
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- eTSH = endogenous thyroid stimulating hormone
- PT: prothrombin time
- T4 = thyroxine

Suggested Reading

- Armstrong, SR, Roberts, BK, and Aronsohn, M. Perioperative hypothermia. *J Vet Emerg Crit Care* 2005;15(1):32–37.
- Dhupa, N. Hypothermia in dogs and cats. *Comp Cont Ed Pract Vet* 1995;17:61–69.
- Moon, PF, and Ilkiw, JE. Surface-induced hypothermia in dogs: 19 cases. *J Am Vet Med Assoc* 1993;2002:437.
- Oncken, A, Kirby, R, and Rudloff, E. Hypothermia in critically ill dogs and cats. *Comp Cont Ed Pract Vet* 2001;23(6):506–520.
- Todd, J, and Powell, LL. Hypothermia. In: Silverstein, DC, and Hopper, K, eds. *Small Animal Critical Care Medicine*, pp. 720–722. St. Louis: Saunders Elsevier, 2009.
- Wingfield, WE. Accidental hypothermia. In: Wingfield, WE, Raffe, MR, (eds.) *The Veterinary ICU Book*, pp. 1116–1129. Jackson, WY: Teton New Media, 2002.

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Hypoxemia



DEFINITION/OVERVIEW

- Hypoxemia is defined as aPaO₂ of less than 80 mmHg.
- Clinically significant desaturation of hemoglobin occurs at a PaO₂ < 60 mmHg and warrants rapid intervention.



ETIOLOGY/PATHOPHYSIOLOGY

- The five causes of hypoxemia are:
 - Low FiO₂
 - Hypoventilation
 - Mismatching of alveolar ventilation and pulmonary perfusion
 - Right-to-left cardiac or intrapulmonary shunting
 - Alveolar-capillary membrane diffusion defect.
- Conditions that result in hypoxemia result from one or more of these causes.
 - Low FiO₂—High altitudes have lower barometric pressures than at sea level and, subsequently, offer lower partial pressure of atmospheric oxygen. Patients attached to a breathing circuit (anesthetic circuit, ventilator) or in an enclosed environment (oxygen cage) could accidentally be exposed to air with a lower FiO₂.
 - Hypoventilation—Conditions associated with central respiratory depression (CNS disease or an anesthetic overdose) or those affecting the respiratory apparatus (upper airway obstruction, restriction of the thoracic cage from pleural space disease, neuromuscular disease, thoracic trauma, diaphragmatic hernia, ascites or severe gastric dilation) can all cause decreased alveolar ventilation.
- V/Q mismatch:
 - V/Q mismatch occurs along a spectrum: on one end alveoli are perfused but not ventilated (low V/Q mismatch). Diseases that create partial filling of alveoli with fluid (i.e., pneumonia, pulmonary edema, pulmonary contusions, neoplasia) or partial obstruction of the terminal airways (i.e., bronchitis) result in regions of impaired gas exchange. On the other end of the spectrum, the alveoli are ventilated but not perfused, resulting in pure dead space ventilation (high V/Q mismatch). Patients with pulmonary thromboembolism represent this group.

- Right-to-left cardiac or intrapulmonary shunting:
 - Physiological right-to-left shunts occur when areas of the lung that are completely unventilated ($V/Q = 0$) due lung lobe consolidation (from pneumonia, atelectasis, edema, neoplasia) are unable to contribute to gas exchange. The deoxygenated blood coming from these unventilated areas of the lung dilutes the arterial partial oxygen pressure and results in hypoxemia. Pathological anatomical shunts are associated with abnormal communication between right and left sides of the circulation (right- to left-sided shunting ventricular septal defects, right- to left-sided shunting patent ductus arteriosus).
- Alveolar-capillary membrane diffusion defect:
 - Diseases that decrease the area or increase the thickness of this gas exchange membrane (e.g., pulmonary edema, pulmonary hemorrhage, pulmonary fibrosis) may potentially cause hypoxemia if patients are exercised, not at rest.

Systems Affected

- CNS—Cerebral hypoxia can result in irreversible brain damage.
- Gastrointestinal—Susceptible to bacterial translocation during periods of hypoxia.



SIGNALMENT/HISTORY

- Brachycephalic breeds may be more susceptible to hypoxemia secondary to upper airway obstruction.
- West Highland White terriers and idiopathic pulmonary fibrosis (Westie lung disease)

Risk Factors/Causes

- Bronchopneumonia, pleural space disease, trauma, anesthesia, prolonged recumbency, cardiac disease, neuromuscular disorders, structural or dynamic upper airway obstruction (e.g., brachycephalic airway syndrome, laryngeal paralysis).

Historical Findings

- The owners may describe increased respiratory rate and effort, cyanosis, coughing, gagging, trauma, exercise intolerance, or collapse.



CLINICAL FEATURES

- Tachypnea, orthopnea, sitting with head and neck extended, restlessness, open mouth breathing, stridor, stertor, nasal flare, cyanotic or pale mucous membranes, coughing, bronchial sounds or crackles and wheezes on auscultation, tachycardia, heart murmurs, arrhythmias and pulse deficits.



DIFFERENTIAL DIAGNOSIS

- Excitement/anxiety, hyperthermia, fever, pain, head trauma, or anemia.



DIAGNOSTICS

- Arterial blood gas
- SpO₂ values below 90 to 92% are considered abnormal.
 - Disadvantages of pulse oximetry are that the probe is most accurate in nonmoving animals when clipped into the tongue or in nonpigmented mucous membranes.
 - The pulse oximeter only indicates the percentage saturation of available hemoglobin molecules, irrespective of the amount of hemoglobin present and of their ability to deliver oxygen to the tissues.

Pathological Findings

Gross Pathologic Findings

- Pale or cyanotic mucous membranes

Histopathologic Findings

- Tissue ischemic necrosis (gastrointestinal tract, brain, heart)



THERAPEUTICS

- Supplemental oxygen therapy
 - Patients with severe hypoventilation despite oxygen supplementation or those requiring high levels of oxygen for prolonged periods may become candidates for mechanical ventilation.
 - Face mask, nasal or nasopharyngeal oxygen cannula, intratracheal, or oxygen cage.

Precautions/Interactions

- Use caution with fluid therapy in animals with pulmonary edema and hypoxia secondary to congestive heart failure.
- Diuretic therapy is indicated in patients with hypoxemia caused by cardiac failure and pulmonary edema.

Diet

- If patient is in respiratory distress, nothing by mouth

Activity

- Patients who are hypoxemic should be minimally stressed and handled.
- Coupage, nebulization therapy, and frequent turnings might help patients with bronchopneumonia dislodge and excrete pulmonary exudates.

Surgical Considerations

- For dogs showing early signs consistent with brachycephalic syndrome, widening the nostrils and shortening the soft palate may confer a long-term favorable prognosis of avoiding complications associated with brachycephalic airway syndrome.



COMMENTS

- Use minimal restraint with handling.
- Provide supplemental oxygen.
- Remember the oxyhemoglobin dissociation curve when handling any patient with respiratory distress and hypoxemia. (See Figure 52.1.)

Client Education

- Owners should be instructed to monitor respiratory rate and effort when their animals are at rest.
- Check for cyanotic mucous membranes.

Patient Monitoring

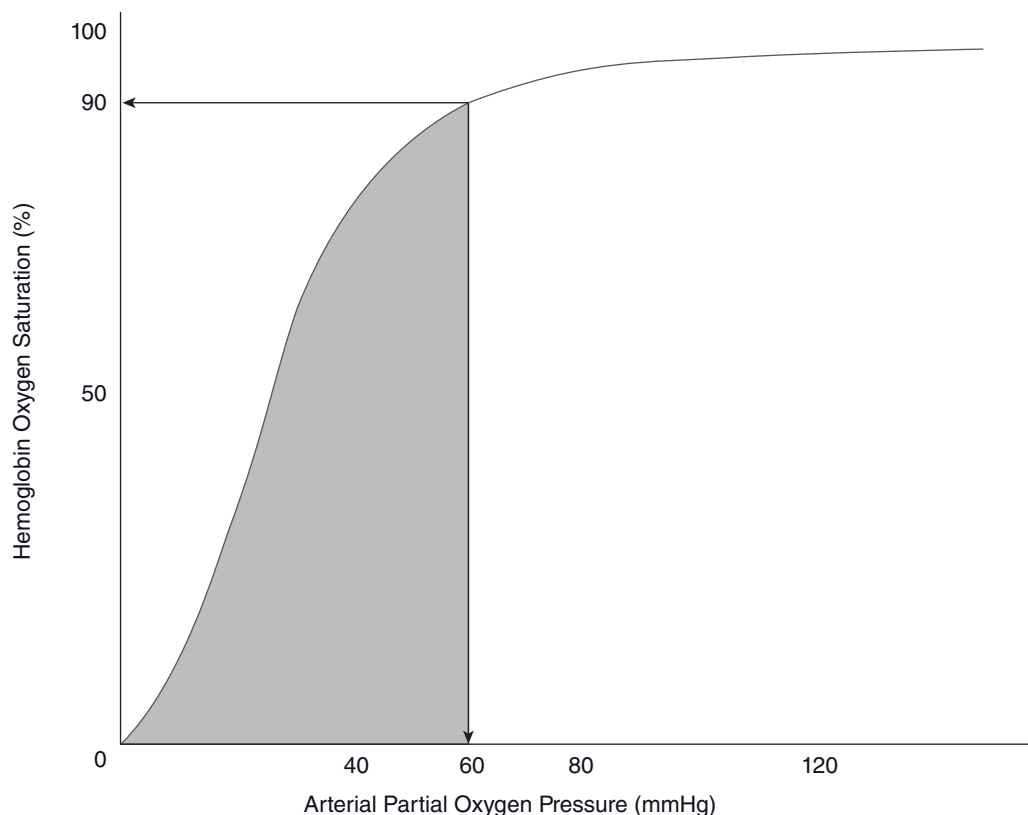
- The effectiveness of supportive (oxygen therapy) and definitive treatment can be assessed by physical examination findings associated with a more comfortable and less anxious patient: reduced respiratory rate and effort, decreased tachycardia and improvement of cyanotic mucous membranes (if present initially).
- Effectiveness of oxygen therapy can be accurately assessed by repeating arterial blood gas analysis and comparing trends based on the alveolar and PaO₂ gradients. Pulse oximetry can be also be used for continual assessment while on oxygen support and without it.

Prevention/Avoidance

- Weight loss for overweight patients.
- Activity restriction during hot weather.
- Early corrective surgery for brachycephalic breeds.

Possible Complications

- Exposure to 60 percent FiO₂ or greater for more than 24 hours can produce signs of oxygen toxicity due to the formation of oxygen-derived free radical species and subsequent pulmonary damage.



■ **Figure 52.1** The curve shows that the oxygen saturation of hemoglobin decreases sharply when the arterial partial oxygen pressure is less than 60 mmHg. Animals with respiratory distress can compensate just above the flexure point of the curve when at rest, and their oxygen hemoglobin saturation is preserved (pulse oximeter oxygen saturation of 90). Any stress may cause further decreases in the arterial partial pressure of oxygen, which will bring the oxygen hemoglobin saturation into the steep downward part of the curve. Therefore, leaving the patient relaxed with oxygen supplementation is the first priority upon arriving to the hospital.

- Arterial blood gas analysis and pulse oximetry should be used to guide oxygen supplementation. If prolonged periods of high FiO_2 are anticipated, mechanical ventilation should be considered.

Expected Course and Prognosis

- Prognosis is dependent on the primary or secondary cause of hypoxia and patient's response to therapy.

Abbreviations

- CNS: central nervous system
- FiO_2 : fractional percentage of inspired oxygen
- PaO_2 : arterial partial pressure of oxygen
- PaCO_2 : arterial partial pressure of carbon dioxide

- SpO₂: indirect measurement of the hemoglobin oxygen saturation of arterial blood made via pulse oximetry
- V/Q: ventilation/perfusion

See Also

- Drowning and Near Drowning

Suggested Reading

Camps-Palau, MA, and Cornick, JL. Small animal oxygen therapy. *Comp Contin Educ Pract Vet* 1999;21(7):1–10.

Clare, M, and Hopper, K. Mechanical ventilation: Indications, goals, and prognosis. *Comp Contin Educ Pract Vet* 2005;27(3):195–208.

Lee, JA, and Drobatz, KJ. Respiratory distress and cyanosis in dogs. In: King, LG, ed. *Textbook of Respiratory Disease in Dogs and Cats*, pp.1–3. Philadelphia: Saunders, 2004.

Martin, L. PaO₂ and the alveolar-arterial PO₂ difference. In: Martin, L, ed. *All You Really Need to Know to Interpret Arterial Blood Gases*, 2nd ed., pp. 55–57. Baltimore: Lippincott Williams & Wilkins, 1999.

Mensack, S, and Murtaugh, R. Oxygen toxicity. *Compend Contin Educ Pract Vet* 1999;21(4): 341–350.

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Immune-Mediated Hemolytic Anemia (IMHA)



DEFINITION/OVERVIEW

- IMHA is a type II hypersensitivity reaction resulting from the production of anti-erythrocyte antibodies that accelerate the destruction or removal of erythrocytes from circulation.
- IMHA can be primary (idiopathic) or secondary to medication or disease.
- Immunosuppression is the backbone of therapy. Additional therapy includes supportive care and treatment of any underlying condition.
- Response to therapy is variable. Mortality is related to refractory anemia, thromboembolism (usually pulmonary), or adverse effects of therapy.



ETIOLOGY/PATHOPHYSIOLOGY

- Anti-erythrocyte antibodies form against normal erythrocyte surface antigens (primary IMHA) or against altered erythrocyte surface antigens (secondary IMHA).
- Cause of secondary IMHA include:
 - Tick-borne disease (ehrlichiosis), babesiosis, mycoplasmosis, cytauxzoonosis
 - Viral disease—FeLV, FIV, FIP
 - Neoplasia (especially lymphoma)
 - Drugs—cephalosporins, methimazole, propylthiouracil
 - Live virus vaccination
 - Heartworm disease
 - Bacterial infection: leptospirosis, bacterial endocarditis
- Antibodies or complement deposition on erythrocyte membranes results in either direct intravascular hemolysis or accelerated extravascular removal of the erythrocyte by the mononuclear phagocytic system in the spleen, liver, and/or bone marrow. Extravascular hemolysis is most common.
- Autoagglutination of erythrocytes occurs when IgM or high titers of IgG cause inter-erythrocytic bridging.
- The anemia of IMHA is usually regenerative. It may be nonregenerative early in the course of disease (2–5 days), if concurrent disease (e.g., renal failure) precludes regeneration, or if the targeted cell is an erythrocyte precursor, and results in the destruction of immature erythrocytes in the marrow.

- IMHA can occur alone, or in combination with other immune-mediated disease (IMT, SLE).
- IMHA is relatively common in dogs; in many cases, an underlying or predisposing cause is not identified. It is uncommon in cats, and is usually secondary to underlying disease.

Systems Affected

- Hemolympathic—Destruction or removal of erythrocytes resulting in anemia, production and release of proinflammatory mediators, DIC, thrombocytopenia, hypercoagulable state, and resultant thrombosis.
- Hepatobiliary—Prehepatic icterus, hyperbilirubinemia, and bilirubinuria are common. Elevated liver enzymes can occur secondary to anemia.
- Cardiovascular—Tachycardia due to hypoxia; murmurs can occur as a result of decreased blood viscosity and turbulent blood flow; chronic anemia may precipitate high output heart failure.
- Respiratory—Hypoxia, tachypnea secondary to anemia or pulmonary thromboembolism.
- Renal/urinary—Pigmenturia with intravascular hemolysis; severe intravascular hemolysis may cause tubular damage.
- Skin—Pallor, icterus.



SIGNALMENT/HISTORY

Breed Predispositions

- Dogs: Cocker spaniel, English springer spaniel, poodle, Irish setter, collie, old English sheepdog, miniature Schnauzer; any breed
- Cats: None reported

Age

- Dogs: mean 5 to 6 years, range 1 to 13 years
- Cats: mean 2 to 3 years, range 0.5 to 9 years
- Dogs: middle aged is most common

Sex

- Neutered female dogs and male cats may have increased risk.

Risk Factors/Causes

- Recent drugs or vaccinations (3–10 days)
- Associated underlying diseases

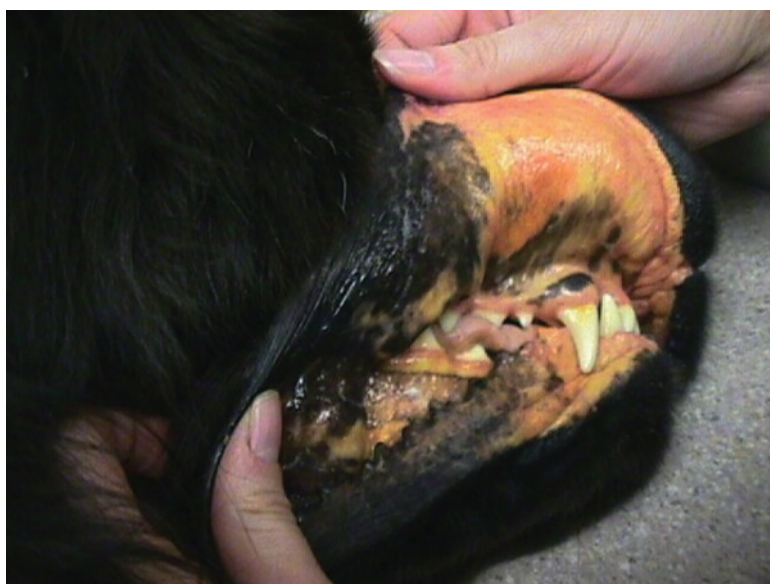
Historical Findings

- Lethargy, depression, inappetence
- Weakness, exercise intolerance
- Pallor with or without icterus
- Pigmenturia (hemoglobinuria)
- Vomiting, diarrhea



CLINICAL FEATURES

- Pallor with or without icterus (Figures 53.1 and 53.2)
- Depression, weakness
- Tachycardia
- Bounding pulses
- Tachypnea
- Pigmenturia
- Splenomegaly or hepatosplenomegaly
- Heart murmur or gallop
- Fever
- Signs of underlying disease—e.g., lymphadenopathy, cavitory effusion.
- Signs of other concurrent immune-mediated disease—e.g., petechiae/ecchymoses, mucocutaneous lesions, chorioretinitis, arthritis.



■ **Figure 53.1** Icteric mucous membranes of a dog with immune-mediated hemolytic anemia.



■ **Figure 53.2** Icteric sclera of a dog with immune-mediated hemolytic anemia.



DIFFERENTIAL DIAGNOSIS

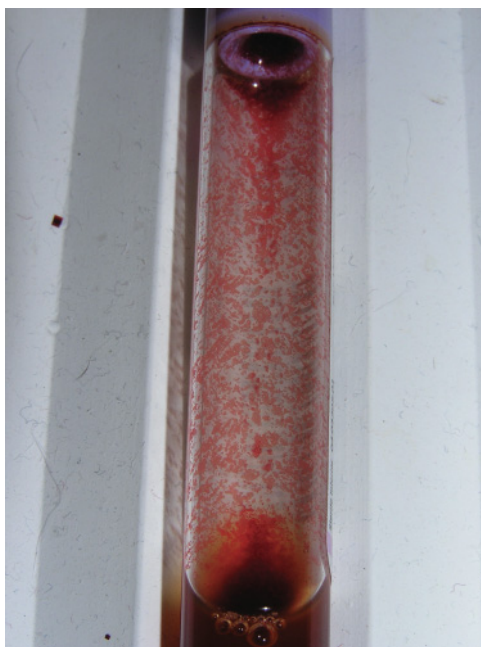
- IMHA must be differentiated from other causes of hemolytic anemia. These include:
- Toxic hemolysis:
 - Zinc toxicity
 - Oxidative injury—acetaminophen, onions, garlic, propylene glycol, snake venom, methylene blue, cephalosporins, Vitamin K, benzocaine, naphthalene (mothballs), skunk musk
 - Copper toxicosis
- Erythroparasites:
 - Babesiosis (*Babesia* spp.)
 - Ehrlichiosis (*Ehrlichia* spp.)
 - Hemobartonellosis (*Mycoplasma haemofelis*, *Haemobartonella canis*)
 - Cytauxzoonosis (*Cytauxzoon felis*)
- Microangiopathic hemolysis:
 - DIC
 - Splenic torsion
 - Hemangiosarcoma
 - Caval syndrome (dirofilariasis)
 - Vasculitis
- Inherited:
 - Pyruvate kinase deficiency
 - Phosphofructokinase deficiency

- B₁₂ deficiency
- Osmotic fragility syndrome
- Nonspherocytic hemolytic anemia of beagles
- Miscellaneous:
 - Hypophosphatemia
 - Iatrogenic changes in osmolarity
 - Histiocytic neoplasia
 - Snake bites



DIAGNOSTICS

- CBC, reticulocyte count:
 - Anemia—usually moderately to markedly regenerative; may be nonregenerative
 - Spherocytosis in dogs
 - Anisocytosis, polychromasia, macrocytosis, nucleated red blood cells—can be seen if regenerative anemia.
 - Neutrophilia, lymphocytosis, monocytosis
 - Microscopic agglutination may be present (Figure 53.3).



■ **Figure 53.3** Macroscopic agglutination observed from same dog with immune-mediated hemolytic anemia (IMHA). Macroscopic agglutination should increase an index of suspicion for IMHA, however, it can also be present due to severe rouleaux formation. Therefore, the saline agglutination test must be performed and evaluated for microscopic agglutination.

- Biochemical profile:
 - Hyperbilirubinemia or hemoglobinemia
 - Elevated hepatic enzymes
- Urinalysis:
 - Hemoglobinuria or bilirubinuria
- In-saline agglutination test:
 - Agglutination persists after addition of one to two drops of normal saline to one drop fresh or EDTA-anticoagulated blood on a glass slide.
 - A negative test does not exclude a diagnosis of IMHA.
- Direct Coombs' test:
 - Detects the presence of autoantibodies or complement on erythrocyte surface.
 - Test is positive in 35 to 60 percent of dogs with IMHA; a negative test does not exclude a diagnosis of IMHA.
 - False-positive tests can occur with previous transfusions, as well as some infectious diseases, drugs, or neoplasia.
- Coagulation testing (platelet count, PT, PTT, D-dimers):
 - Usually normal.
 - Marked thrombocytopenia may indicate concurrent IMT.
 - Mild thrombocytopenia, elevated D-dimers, or elevated PTT may indicate consumption (DIC or thrombosis).
- Imaging (radiography, ultrasonography):
 - Splenomegaly, or hepatosplenomegaly
 - Thorax usually normal; may be evidence of PTE
- Bone marrow evaluation:
 - Indicated if nonregenerative anemia, marked thrombocytopenia or leucopenia.
 - Usually reveals erythroid hyperplasia; if anemia nonregenerative, may reveal maturation arrest or erythroid hypoplasia.
 - Erythrophagocytosis sometimes evident.
- Other diagnostic testing should be aimed at ruling out differential diagnoses, and identifying (or ruling out) an underlying cause for IMHA. May include:
 - Serology and PCR. Dogs: ehrlichiosis, babesiosis, leptospirosis. Cats: FeLV, FIV, *Mycoplasma haemofelis*, with or without ehrlichiosis.
 - Bacterial culture of any potential infections.



THERAPEUTICS

- The objectives of therapy are:
 - Suppression of immune-mediated hemolysis, and reversal of anemia
 - Treatment of underlying disease, if present
 - Support of the patient through the anemic crisis
 - Prevention of catastrophic consequences (e.g., thromboembolism)
 - Gradual weaning of therapy over subsequent months such that remission is sustained.

- Inpatient care is indicated in the acute hemolytic state, if the patient is unable to tolerate oral medication, is severely thrombocytopenic ($<40,000$ platelets/ μl), or develops complications such as PTE, DIC, or heart failure.
- Inpatient care should focus on optimizing hydration, perfusion, oxygen delivery, and acid-base balance.
- Minimize stress.
- Minimize risk of thrombosis through use of less thrombogenic catheters, routine flushing of catheters with heparinized saline, and maintenance of perfusion.
- Restrict venipuncture and minimize sample volumes in small patients.
- Be cautious regarding the risk of volume overloading in patients with chronic anemia.

Drug(s) of Choice

Glucocorticoids

- Prednisone/prednisolone. Small dogs and cats: 1 to 2 mg/kg PO every 12 hours. Large dogs (>20 kg): 20 mg PO every 12 hours. If platelet count normal ($>200,000/\mu\text{l}$) after 3 to 4 weeks, taper dose by 25 to 50 percent. If count remains stable, continue to taper by 25 to 50 percent every 3 to 4 weeks, to lowest effective dose.
- Prednisolone is preferable to prednisone in cats.
- Dexamethasone (0.2–0.25 mg/kg IV or SQ every 12 hours) is an acceptable alternative to prednisone if oral medication is not tolerated.
- Adjunctive immunosuppressive therapy is generally recommended early in management, particularly in patients with intravascular hemolysis, autoagglutination, or those refractory to glucocorticoid therapy (inadequate response by 5–7 days).

Dogs

- Azathioprine (2 mg/kg PO every 24 hours). Decrease frequency to every 48 hours after glucocorticoid discontinuation, or if a decrease in white blood cell count. Note: May take 2 to 4 weeks to effect.
- Cyclosporine (5 mg/kg PO every 12 hours)
- Mycophenolate mofetil (10–20 mg/kg PO every 12 hours)

Cats

- Cyclosporine (5 mg/kg PO every 12 hours)
- In cases that relapse with dose reduction of glucocorticoids, the clinician should consider changing to, or adding, another immunosuppressive agent.
- Blood transfusion:
 - Indicated if anemic crisis or significant signs referable to anemia. Decision to transfuse should be based on patient's clinical signs, not merely PCV.
 - Packed red blood cells (10 ml/kg, over 4 hours) are indicated if severe anemia.

- If packed red blood cells are not available, transfusion with whole blood (20 ml/kg over 4 hours) or a hemoglobin-based oxygen solution (Oxyglobin, 10–30 ml/kg over 4–8 hours) is an acceptable alternative.
- All cats must be typed or cross-matched prior to blood transfusion to ensure a compatibility. Cross-matches should be performed with any subsequent transfusions in dogs and cats. If an animal is autoagglutinating, a cross-match procedure cannot be performed. However, there are blood typing kits available that can be performed on blood that is saline agglutination positive (IVD Scientific Service Laboratory, www.alvediavet.com)
- Thromboprophylaxis (dogs):
 - Ultra-low dose aspirin (0.5 mg/kg PO every 24 hours)
 - If thromboembolism is present: low molecular weight heparin or heparin CRI protocol.
- Gastroprotectants:
 - H₂ receptor antagonists while on high-dose glucocorticoids
 - Sucralfate with or without proton pump inhibitor if suspected gastrointestinal ulceration
- Intravenous fluid therapy if indicated for dehydration or hypoperfusion.

Precautions/Interactions

- Avoid medications associated with secondary IMHA or bone marrow suppression, as well as therapies that cause immune stimulation (e.g., vaccines).
- Do not use azathioprine in cats.
- If using azathioprine, monitor liver enzymes and CBC regularly.

Alternative Drugs

- Intravenous human immunoglobulin (0.5–1.5 g/kg IV infusion over 6–12 hours) has been suggested for patients with refractory IMHA, and those with aggressive hemolysis or autoagglutination. Effect can be rapid, but sustained immunosuppression is unlikely. Administered together with glucocorticoids with or without adjunctive immunosuppressive therapy.

Activity

- Enforced restricted activity until stable

Surgical Considerations

- Splenectomy may be considered for cases refractory to medical management. This is generally reserved for patients that fail to achieve sustained remission following multiple combination immunosuppressive regimens.



COMMENTS

Client Education

- IMHA and associated complications may be fatal.
- The patient will need to be on medications for months. In some cases, lifelong treatment is necessary.
- Relapses and recurrences are possible.
- Regular recheck visits will be necessary, adding to the financial and time commitment.
- There are likely to be clinical adverse effects of corticosteroids; these will diminish as the dose is decreased, and will abate when drug is discontinued.
- Appropriate precautions for immunosuppressed patients.
- Monitor for signs of recurrent anemia, thromboembolism (e.g., tachypnea, respiratory distress), or adverse drug reactions (e.g., inappetence, lethargy, melena, pollakiuria).
- Live virus vaccination and drugs associated with secondary IMHA should be avoided.

Patient Monitoring

Inpatient Monitoring

- Signs of anemia—tachycardia, bounding pulses, tachypnea, decreasing PCV
- Signs of thromboembolism—tachypnea, respiratory distress, abdominal effusion
- Adverse effects of therapy (e.g., volume overload, transfusion reaction)
- PCV every 4 to 12 hours, depending on rate of change.

Outpatient Monitoring

- CBC—weekly until normal, then every other week for 2 to 3 months, then monthly until 3 months following discontinuation of drugs. If any evidence of relapse, increase frequency.
- Azathioprine—CBCs as noted, chemistry profile (liver parameters) monthly or if concerns.
- Cyclosporine—trough drug concentration should be assessed if inadequate response, or suspicion of toxicity.

Possible Complications

- Refractory anemia
- Thromboembolic disease (pulmonary or other organ)
- DIC
- Infection secondary to immunosuppression
- Gastrointestinal ulceration due to glucocorticoid therapy in dogs
- Diabetes mellitus secondary to glucocorticoid therapy in cats
- Azathioprine: potential for myelosuppression or hepatotoxicity

- Transfusion reaction
- Acute renal failure
- Death

Expected Course and Prognosis

- Initial response (slowing of hemolysis, increase in PCV) is usually seen within 7 days; normalization of PCV may take weeks.
- Response is significantly slower in patients with nonregenerative anemia; it does not warrant a poorer prognosis.
- A poorer prognosis is associated with intravascular hemolysis, serum bilirubin concentration >5 mg/dl, hypoalbuminemia, and severe thrombocytopenia.
- Mortality varies with severity of disease, and ranges from 25 to 80 percent.
- Thromboembolism is a significant potential consequence, with reported prevalence of 30 to 80 percent.
- Patients that survive the acute crisis and leave the hospital have a relatively good prognosis.
- Patients need to be on immunosuppressive therapy for months.
- Relapse can occur with tapering of therapy, and is an indication for adjustment of the immunosuppressive therapy protocol.
- Recurrence is possible.

Synonyms

- Immune-mediated anemia
- Autoimmune hemolytic anemia (AIHA)

Abbreviations

- CBC: complete blood cell count
- CRI: continuous rate infusion
- DIC: disseminated intravascular coagulation
- EDTA: ethylene diamine tetraacetic acid
- FeLV: feline leukemia virus
- FIP: feline infectious peritonitis virus
- FIV: feline immunodeficiency virus
- IgG: immunoglobulin G
- IgM: immunoglobulin M
- IMHA: immune-mediated hemolytic anemia
- IMT: immune-mediated thrombocytopenia
- IV: intravenously
- PCR: polymerase chain reaction
- PCV: packed cell volume
- PO: by mouth

- PT: prothrombin time
- PTE: pulmonary thromboembolism
- PTT: partial thromboplastin time
- SLE: systemic lupus erythematosus
- SQ: subcutaneously

Suggested Reading

- Balch, A, and Mackin, A. Canine immune mediated hemolytic anemia. *Compend Contin Educ Pract Vet* 2007;217–239.
- Giger, U. Regenerative anemias caused by blood loss or hemolysis. In: Ettinger, SJ, Feldman, EC, eds. *Textbook of Veterinary Internal Medicine*, 6th ed., pp. 1886–1907. St. Louis: Elsevier, 2005.
- Kohn, B, Weingart, C, Eckmann, V, et al. Primary immune-mediated hemolytic anemia in 19 cats: Diagnosis, therapy and outcome (1998–2004). *J Vet Intern Med* 2006;20:159–166.
- Miller, E. Immune mediated hemolytic anemia. In: Bonagura, JD, and Twedt, DC, eds. *Kirk's Current Veterinary Therapy XIV*, pp. 266–271. St. Louis: Saunders, 2009.
- Pick, CJ, Junius, G, Dekker, A, et al. Idiopathic immune-mediated hemolytic anemia: Treatment outcome and prognostic factors in 149 dogs. *J Vet Intern Med* 2008;22:366–373.
- Weinkle, TK, Center, SA, Randolph, JF, et al. Evaluation of prognostic factors, survival rates and treatment protocols for immune-mediated hemolytic anemia in dogs: 151 cases (1993–2002). *J Am Vet Med Assoc* 2005;226:1869–1880.

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Intussusception



DEFINITION/OVERVIEW

- Gastrointestinal intussusception is the telescoping or prolapsing of one portion of the gastrointestinal tract into the lumen of an adjoining part of intestine or stomach. This occurs most commonly in the jejunum (Figure 54.1) or at the ileocolic junction, although gastroesophageal or pylorogastric intussusceptions are also possible. The parts of a typical intussusception are the proximal (orad) intussusceptum, the prolapsed portion, and the distal (aborad) intussusciens, the receiving portion. Reverse and multiple intussusceptions may also occur. Sliding intussusceptions (those that occur and then reduce spontaneously) have also been reported.

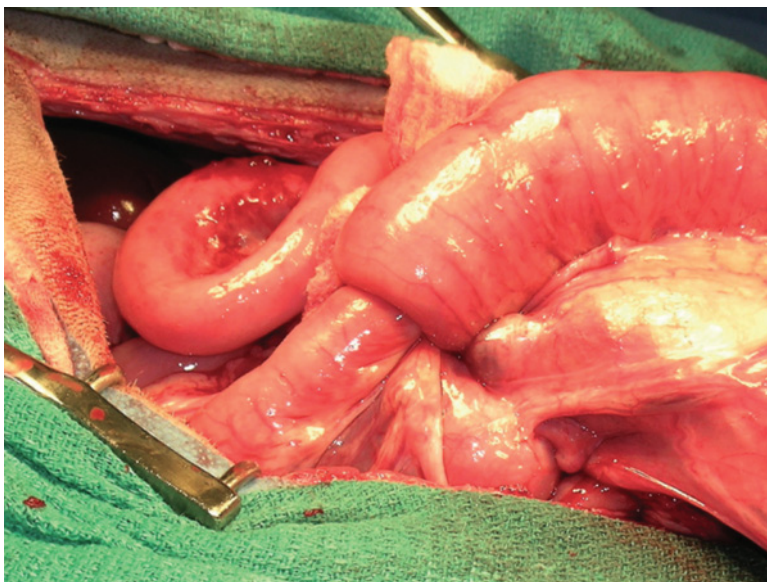


ETIOLOGY/PATHOPHYSIOLOGY

- Intussusceptions are often associated with gastroenteritis attributed to intestinal parasitism, focal and linear foreign bodies, intestinal mass, dietary indiscretion, or viral infection. Previous abdominal surgery has also been suspected as a causative factor, although in the majority of cases of intussusception the cause is unknown.

Systems Affected

- Gastrointestinal—Intussusceptions may cause a complete or partial obstruction and result in vomiting, melena, or hematochezia. Inappetence and weight loss may occur with chronic or sliding intussusceptions. The tissue involved in the intussusception may become devitalized and result in gastrointestinal necrosis and leakage into the abdominal cavity.
- Cardiovascular—Intussusceptions that result in complete gastrointestinal obstruction, breakdown of the mucosal barrier, or wall necrosis have the high likelihood of causing hypovolemic and septic shock.
- Respiratory—Animals with acute gastroesophageal intussusception may present in severe respiratory distress due to the presence of the gas-distended stomach within the thoracic cavity or due to aspiration pneumonia from severe vomiting.



■ **Figure 54.1** A jejunojejunal intussusception in a 10-week old Weimaraner.



SIGNALMENT/HISTORY

- Intussusceptions occur in both dogs and cats and seem to predominantly affect younger animals less than 1 year of age. German shepherd dogs and Siamese cats may be overrepresented, although intussusceptions can occur in any breed. There does not appear to be a gender predisposition.
- Clinical signs associated with intussusception are influenced by location, completeness, and duration of obstruction. Acute intussusceptions have a history most consistent with an acute abdomen: vomiting, bloody diarrhea, and abdominal pain. Animals with chronic intussusceptions may have clinical signs that are vaguer: inappetence, weight loss, and diarrhea.
- Historical information may be valuable in aiding the diagnosis of intussusception because many animals will have a recent history of illness, abdominal surgery, or environmental change.



CLINICAL FEATURES

- Physical examination may reveal a guarded painful abdomen.
- Often an elongated large tubular structure can be palpated within the abdomen, representing a thickened loop of intestine.
- Occasionally, the intussusceptum may protrude through the anus mimicking a rectal prolapse.



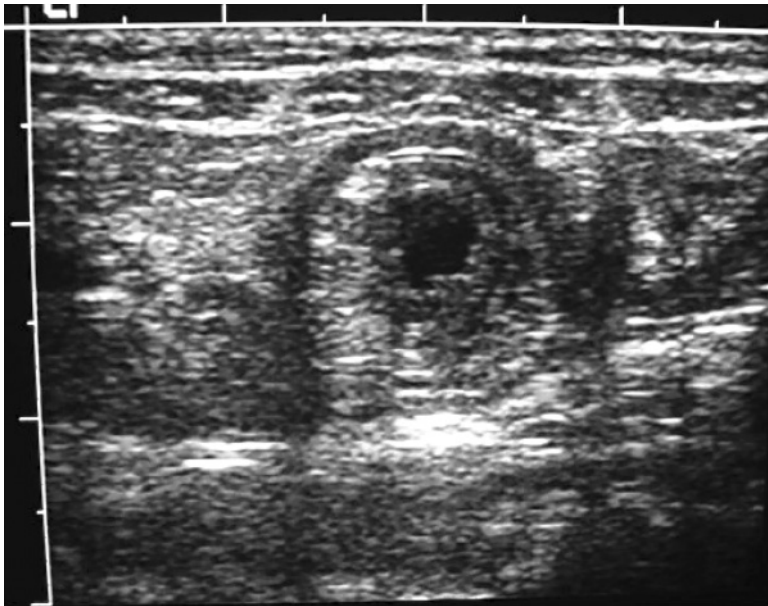
DIFFERENTIAL DIAGNOSIS

- Focal gastrointestinal foreign bodies
- Linear gastrointestinal foreign bodies
- Intestinal volvulus
- Gastroenteritis



DIAGNOSTICS

- Survey abdominal radiographs—Plain abdominal radiographs may have variable signs. A large soft tissue tubular structure may be visualized. Incomplete obstructions do not usually result in gas accumulation within the intestinal lumen. A barium enema or pneumocolonogram may help with diagnosis of ileocolic intussusceptions.
- Abdominal ultrasound—This modality is particularly useful in identifying intussusceptions. In a transverse plane, intussusceptions appear as a multilayered target-like image with alternating hyperechoic and hypoechoic concentric rings; in a longitudinal plane, there are alternating hyperechoic and hypoechoic parallel lines (Figure 54.2). Although the “target sign” or “bulls-eye” is considered to be pathognomonic



■ **Figure 54.2** A transverse ultrasound image of an ileocolic intussusception demonstrating the classic target sign appearance.

for intestinal intussusception, care must be taken to visualize the structure in multiple planes to avoid misdiagnosis. A recent case report describes how healthy intestine, enteritis, and postpartum uterine involution can have an ultrasonographic target-like appearance in some imaging planes.

- Laboratory findings may include electrolyte abnormalities, acid-base disturbances, anemia, hypoalbuminemia, stress or inflammatory leukograms, and evidence of dehydration.

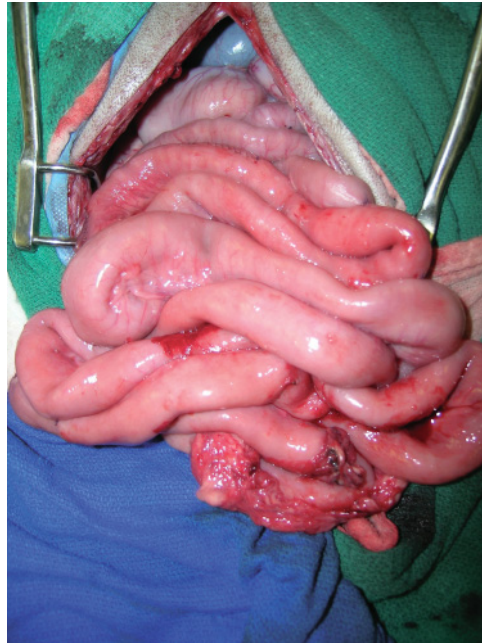


THERAPEUTICS

- Although spontaneous reduction of intestinal intussusception is possible, surgical intervention is the treatment of choice. Prior to surgery, the animal's hemodynamic and electrolyte status should be stabilized, although surgery should not be delayed unnecessarily. Although intestinal resection may or may not be required, prophylactic antibiotics are indicated as the viability of the intestine is unknown and because there is increased infection risk with intestinal obstruction due to mucosal breakdown with potential bacterial overgrowth and translocation.

Surgical Considerations

- The objective of surgery is to reestablish a patent gastrointestinal tract either through reduction of the intussusception or by resection of the affected segment. Reduction of the intussusception should be attempted by placing gentle traction on the intussusceptum while gently pushing on the intussusciens. If reduced, the involved portion of the intestine is evaluated for perforations, necrosis, or other signs of poor viability. Subjective measures utilized to assess intestinal viability include color, thickness, peristalsis, and arterial pulsation. Resection and anastomosis have been reported to be necessary in over 80 percent of cases due to vascular compromise, devitalized tissue, intestinal perforation, and adhesions.
- Controversy exists over whether measures should be taken to prevent recurrence of intestinal intussusception. This is accomplished through enteroplication (or enteroenteropexy), which is the creation of permanent serosal adhesions between adjacent segments of small intestine (Figure 54.3). To perform this procedure, gentle loops of small intestine from the duodenocolic ligament to the ileocolic junction are placed side by side and secured in this formation with variably spaced simple interrupted partial-thickness sutures using 4-0 absorbable monofilament material. Care must be taken to avoid abrupt angles of the intestinal loops to minimize the risk of postoperative intestinal obstruction. Both intussusception recurrence and severe postoperative complications associated with enteroplication have been reported in the dog and cat.



■ **Figure 54.3** Intraoperative photograph showing the small intestine gently looped in preparation of enteroplication.



COMMENTS

Possible Complications

- The risk of possible complications from enteroplication must be weighed against the risk of possible recurrence. At this time, the only study investigating this problem found that there is similar likelihood (approximately 20 percent) between these two scenarios. Therefore, it is left to the discretion of the veterinarian whether enteroplication is to be performed.

Expected Course and Prognosis

- The prognosis for animals with intussusceptions is dependent on the location and completeness of the obstruction, as well as the duration of the condition. Rapid recognition and treatment contribute to improved survival. However, the prognosis worsens with intestinal perforation and peritonitis. Recent studies report successful outcomes in over 80 percent of cases.

Synonyms

- Intestinal invagination; intestinal telescoping

Suggested Reading

- Applewhite, AA, Cornell, KK, and Selcer, BA. Diagnosis and treatment of intussusceptions in dogs. *Compend Contin Educ Pract Vet* 2002;24:110–126.
- Applewhite, AA, Hawthorne, JC, and Cornell, KK. Complications of enteroplication for the prevention of intussusception recurrence in dogs: A retrospective study (1989–1999). *J Amer Vet Med Assoc* 2001;219:1415–1418.
- Hedlund, CS. Surgery of the small intestine. In: Fossum, TW, ed. *Small Animal Surgery*, 3rd ed, pp. 311–316. St. Louis: Mosby, 2007.
- Patsikas, MN, Papazoglou, LG, and Adamama-Moraitou, KK. Spontaneous reduction of intestinal intussusception in five young dogs. *J Amer Anim Hosp Assoc* 2008;33:44–47
- Patsikas, MN, Papazoglou, LG, Papaioannou, NG, et al. Normal and abnormal ultrasonographic findings that mimic small intestinal intussusception in the dog. *J Am Anim Hosp Assoc* 2004;40:147–151.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Bradford C Dixon

Immune-Mediated Thrombocytopenia (IMT)



DEFINITION/OVERVIEW

- An immune-mediated disease that results from the development of antiplatelet antibodies that accelerate destruction and/or removal of platelets from circulation. IMT can be primary (idiopathic) or secondary to medication or disease.
- Diagnosis is aimed at the elimination of other potential causes for thrombocytopenia, and the identification of underlying disease.
- Morbidity and mortality are related to bleeding; this can be massive, or into a vital organ (e.g., brain, lungs).
- Immunosuppression is the backbone of therapy. Additional therapy includes supportive care and treatment of any underlying condition.
- Response to treatment is generally rapid. If the patient survives the initial period until platelet count increases, long-term prognosis is relatively good.



ETIOLOGY/PATHOPHYSIOLOGY

- IgG antibodies bind to platelet surfaces and result in accelerated platelet destruction and removal.
- Primary (idiopathic) IMT results from antibodies directed against normal platelet surface antigens. This can occur alone, or in combination with other immune-mediated disease (i.e., IMHA, SLE).
- Secondary IMT occurs when antibodies target non-self-antigens that have been adsorbed onto the platelet surface or when immune complexes bind to platelet surface. Causes include:
 - Tick-borne disease (ehrlichiosis), Rocky Mountain spotted fever, bartonellosis
 - Viral disease—FeLV, FIV
 - Neoplasia (especially lymphoma)
 - Drugs—potentiated sulfonamides
 - Live virus vaccination
 - Heartworm disease
 - Chronic bacterial infection



■ **Figure 55.1** Petechial hemorrhages on the gums of a dog with immune-mediated thrombocytopenia.

- Significant thrombocytopenia ($<40,000\text{--}50,000/\mu\text{l}$) results in spontaneous bleeding, particularly in the skin and mucosal surfaces.
- IMT is relatively common in dogs. It is uncommon in cats, and is usually secondary to underlying disease (often viral).
- Secondary IMT may have a higher incidence in areas where associated infectious diseases are endemic.

Systems Affected

- Hemic/Lymphatic/Immune —destruction or removal of platelets (thrombocytopenia), anemia (if bleeding or concomitant IMHA), and production and release of proinflammatory mediators may result in DIC.
- Cardiovascular—failure of primary hemostasis results in bleeding, usually manifested as petechiae or ecchymoses, especially of skin and mucosal surfaces.
- Skin—petechiae/ecchymoses. (Figures 55.1 and 55.2)
- Gastrointestinal—hemorrhage, hematemesis, melena.
- Urologic—urinary hemorrhage/hematuria.
- Respiratory—pulmonary hemorrhage, respiratory difficulty, cough, hemoptysis, epistaxis.
- Eyes—scleral or retinal hemorrhage, hyphema (Figure 55.3).
- Nervous—intracranial hemorrhage, seizures.



■ **Figure 55.2** Severe petechiae on the ventral abdomen of a dog with immune-mediated thrombocytopenia.



■ **Figure 55.3** Hyphema in a dog with thrombocytopenia.



SIGNALMENT/HISTORY

Breed Predispositions

- Dogs: Cocker spaniel, poodles, Old English sheepdogs, Rottweilers have increased incidence; any breed
- Cats: None reported

Age

- Dogs: middle aged is most common
- Cats: mean 2 to 3 years, range 0.5 to 9 years

Sex

- Female dogs have increased risk.

Risk Factors/Causes

- Recent drugs or vaccinations (3–10 days)
- Associated underlying diseases

Historical Findings

- Lethargy, depression, inappetence, weakness
- Bleeding that is apparent to the owner (e.g., petechiae, epistaxis, melena, pigmenturia)
- Bleeding that is not apparent (e.g., blindness due to hyphema)



CLINICAL FEATURES

- Cutaneous or mucosal petechiae or ecchymoses
- Hyphema, retinal/scleral hemorrhage
- Epistaxis
- Melena, hematochezia
- Hematuria
- Tachypnea, adventitious lung sounds
- CNS signs, including changes in consciousness and localized deficits



DIFFERENTIAL DIAGNOSIS

IMT must be differentiated from other causes of thrombocytopenia. These include:

- Decreased platelet production:
 - Pure megakaryocytic hypoplasia (platelets only)—vaccination (i.e., panleukopenia), viral (i.e., FeLV, FIV), estrogen toxicity, phenobarbital toxicity

- Panhypoplasia (including other blood cell lines)—myelophthisis, myelofibrosis, hematopoietic neoplasia, infectious disease (i.e., FeLV, FIP, FIV, chronic ehrlichiosis, sepsis), or drug associated (i.e., chemotherapy, griseofulvin, methimazole, albendazole)
- Dysthrombopoiesis—myelodysplastic syndromes
- Increased platelet consumption or sequestration:
 - DIC
 - Profound, acute hemorrhage
 - Splenic torsion
 - Vasculitis
 - Microangiopathy—hemangiosarcoma, splenic disease
- Nonimmune platelet destruction:
 - Viral—FeLV, FIV, FIP, parvovirus
 - Rickettsial, protozoal—ehrlichiosis, hemobartonellosis, cytauxzoonosis
 - Bacterial—bacteremia, leptospirosis, salmonellosis
 - Fungal—histoplasmosis, disseminated candidiasis
 - Snake envenomation
- Normal breed variation:
 - Low platelet counts can be normal in greyhounds, Cavalier King Charles spaniels, and Shiba Inus.
- Spurious
 - Platelet clumping due to errors in collection or handling will result in artificially low platelet counts.
 - A markedly decreased platelet count ($<50,000/\mu\text{l}$) in the absence of other cell line anomalies (nonregenerative anemia, leukopenia) is suggestive of IMT.



DIAGNOSTICS

Platelet Count

- Should be performed in any patient with a possible bleeding disorder.
- Counts can be performed manually (hemocytometer) or via automated counters in dogs. Automated platelet counting is inaccurate in cats; platelet counts must be performed manually.

Blood Smear Evaluation

- Indicated where platelet count is not immediately available and to verify findings of platelet counts.
- The smear should be carefully examined for platelet clumps, which preclude an accurate count.
- A platelet count can be estimated by multiplying the average platelet count per high power field (100 \times) by 15,000.
- Large platelets are suggestive of regeneration in dogs.

Complete Blood Count

- Thrombocytopenia invariably present; usually marked ($<50,000/\mu\text{l}$)
- Anemia may be present if bleeding or concurrent IMHA. Usually regenerative; may be nonregenerative if early ($<3\text{--}5$ days) or concurrent disease precludes regeneration.
- Neutrophilia sometime present.

Biochemical Profile

- No specific abnormalities; abnormalities may reflect underlying disease.

Coagulogram (PT, aPTT, D-dimers)

- Should be performed to rule out consumptive coagulopathy.
- Normal with IMT.

Thoracic Radiographs

- Indicated if respiratory compromise, or if potential for underlying neoplasia.
- No specific abnormalities; may be suggestive of pulmonary hemorrhage or underlying neoplasia.

Bone Marrow Evaluation

- Ideally should be performed in all cases, except where a consumptive platelet disorder is evident.
- Is definitely indicated with refractory thrombocytopenia, if multiple cell lines affected (i.e., leukopenia, nonregenerative anemia), or if atypical cells are evident on blood smear cytology.
- Megakaryocytic hyperplasia indicates platelet destruction and is typical (but not pathognomonic) for IMT. Megakaryocytic hypoplasia can occur in some cases of IMT if antibodies are directed against early precursors. It is, however, unusual, and other causes for decreased platelet production should be pursued.

Other Laboratory Tests

- Other diagnostic testing should be aimed at ruling out differential diagnoses and identifying (or ruling out) an underlying cause for IMT:
 - Abdominal ultrasonography
 - Serology for viral or tick-borne disease. Dogs: Ehrlichiosis, bartonellosis, Rocky Mountain Spotted Fever. Cats: FeLV, FIV, with or without ehrlichiosis.
 - Bacterial culture of any potential infections.



THERAPEUTICS

- The objectives of therapy are:
 - Suppression of the immune system and thus the immune-mediated platelet destruction, such that platelet numbers normalize
 - Treatment of underlying disease, if present
 - Support of the patient through the bleeding crisis
 - Prevention of catastrophic hemorrhage
 - Gradual weaning of therapy over subsequent months such that remission is sustained.
- Inpatient care is indicated with severe thrombocytopenia ($<40,000/\mu\text{l}$), active bleeding, inability to tolerate oral medication, or development of complications (pulmonary or CNS hemorrhage).
- Restrict venipuncture, and avoid phlebotomy from central veins.
- Minimize risk of bleeding through careful handling.
- Outpatient care when risk of bleeding is decreased (platelet count $>40,000/\mu\text{l}$), anemia is stabilized, and oral medications are tolerated.

Drug(s) of Choice

- Glucocorticoids
 - Prednisone/prednisolone. Small dogs and cats: 1 to 2 mg/kg PO every 12 hours. Large dogs ($>20\text{ kg}$): 20 mg PO every 12 hours. If platelet count is normal ($>200,000/\mu\text{l}$) after 3 to 4 weeks, taper dose by 25 to 50 percent. If count remains stable, continue to taper by 25 to 50 percent every 3 to 4 weeks, to lowest effective dose.
 - Prednisolone is likely preferable to prednisone in cats.
 - Dexamethasone (0.2–0.25 mg/kg IV or SQ every 12 hours) is an acceptable alternative to prednisone if oral medication is not tolerated.
- Vincristine (0.02 mg/kg strictly IV once only) may effect a rapid increase in platelet count.
- Adjunctive immunosuppressive therapy should be considered in cases refractory to glucocorticoid therapy; if inadequate response by 5 to 7 days, or if platelet count decreases with attempts to wean glucocorticoids:
 - Cyclosporine (5 mg/kg PO every 12 hours) in dogs and cats
 - Azathioprine (2 mg/kg PO every 24 hours) in dogs. Decrease frequency to every 48 hours after glucocorticoid discontinuation, or if a decrease in white blood cell count.
 - Mycophenolate mofetil (10–20 mg/kg PO every 12 hours) in dogs
- Intravenous human immunoglobulin (0.5–1.5 g/kg IV infusion over 6–12 hours) has been suggested to be of benefit in initial therapy. Effect can be rapid, but sustained immunosuppression is unlikely. Administer together with glucocorticoids with or without adjunctive immunosuppressive therapy.

- Gastroprotectants:
 - H₂ receptor antagonists while on high-dose glucocorticoids
 - Sucralfate with or without proton pump inhibitor if suspected gastrointestinal ulceration
- Intravenous fluid therapy if indicated for dehydration or hypoperfusion.
- Blood transfusion:
 - If active life-threatening hemorrhage due to thrombocytopenia: platelet concentrate, platelet-rich plasma, or fresh whole blood (20 ml/kg).
 - Packed red blood cells (10 ml/kg, over 4 hours) are indicated if severe anemia. This is aimed to increase oxygen carrying capacity but will have no effect on platelet count or hemostasis. Decision to transfuse should be based on patient's clinical signs, not only PCV.

Precautions/Interactions

- Avoid medications associated with secondary IMT or bone marrow suppression, as well as therapies that cause immune stimulation (e.g., vaccines).
- Avoid drugs that inhibit platelet function (e.g., NSAIDs).
- Do not use azathioprine in cats.
- Vincristine should only be used if adequate bone marrow function is assured and following diagnostic workup for underlying neoplasia.
- Vincristine must be given strictly IV; extravasation is extremely caustic.

Activity

- Enforce restricted activity until platelet count approaches normal range.

Surgical Considerations

- Splenectomy should be considered in cases refractory to medical management. This is generally reserved for patients that fail to achieve remission following multiple combination immunosuppressive regimens.



COMMENTS

Client Education

- IMT and associated complications can be fatal, particularly in the acute period until partial remission is achieved. If the patient survives this period, prognosis is relatively good.
- The patient will need to be on medications for months. In some cases, lifelong treatment is necessary.
- Relapses and recurrences are possible.
- Regular recheck visits will be necessary, adding to the financial and time commitment.
- There are likely to be clinically significant adverse effects of corticosteroids; these will diminish as the dose is decreased, and will abate when drug is discontinued.

- Use appropriate precautions for immunosuppressed patients.
- Monitor for signs of recurrent bleeding, or adverse drug reactions (e.g., inappetence, lethargy, melena, pollakiuria).
- Live virus vaccination and drugs associated with secondary IMT should be avoided.

Patient Monitoring

Inpatient Monitoring

- Signs of anemia—Tachycardia, bounding pulses, tachypnea, decreasing PCV
- Signs of bleeding—Respiratory rate and effort, mentation, stool, urine
- Adverse effects of therapy (e.g., volume overload, transfusion reaction)
- Platelet count every 48 hours until $>50,000$

Outpatient Monitoring

- Platelet count—Weekly until normal, then every other week for 2 to 3 months, then monthly until 3 months following discontinuation of drugs. If any evidence of relapse, increase frequency of counts.
- CBC—Performed with platelet counts if other cell lines affected, and if the patient is on azathioprine therapy.
- Azathioprine—CBCs as noted, chemistry profile (liver parameters) monthly or if concerns.
- Cyclosporine—Trough drug concentration should be assessed if inadequate response, or suspicion of toxicity.

Possible Complications

- Refractory thrombocytopenia
- Massive hemorrhage and hemorrhagic shock
- CNS hemorrhage
- Pulmonary hemorrhage
- Thromboembolism or DIC (rare, unless concomitant IMHA)
- Infection secondary to immunosuppression
- Gastrointestinal ulceration due to glucocorticoid therapy in dogs
- Diabetes mellitus secondary to glucocorticoid therapy in cats
- Azathioprine: potential for myelosuppression and/or hepatotoxicity or pancreatitis
- Transfusion reaction

Expected Course and Prognosis

- Partial remission (platelet count $>50,000$) generally occurs within 2 to 7 days.
- Complete remission (platelet count $>200,000$) generally takes 1 to 3 weeks.
- Negative prognostic indicators include intracranial and intrapulmonary hemorrhage, and underlying neoplasia.
- Severity of thrombocytopenia is not a prognostic indicator.
- Mortality is reported to be approximately 30 percent.
- Patients that survive the period from presentation to partial remission have a good prognosis.

- Transient thrombocytosis is not unusual following therapy, and is without risk.
- Patients need to be on immunosuppressive therapy for months.
- Relapse can occur with tapering of glucocorticoid therapy, and is an indication for adjunctive immunosuppressive therapy.

Synonyms

- Idiopathic thrombocytopenic purpura
- Autoimmune thrombocytopenia

Abbreviations

- aPTT: activated partial thromboplastin time
- CBC: complete blood count
- CNS: central nervous system
- DIC: disseminated intravascular coagulation
- FeLV: feline leukemia virus
- FIV: feline immunodeficiency virus
- FIP: feline infectious peritonitis
- IgG: immunoglobulin G
- IMHA: immune-mediated hemolytic anemia
- IMT: immune mediated thrombocytopenia
- IV: intravenously
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PCV: packed cell volume
- PO: by mouth
- PT: prothrombin time
- PTT: partial thromboplastin time
- SQ: subcutaneously

Suggested Reading

- Bianco, D, Armstrong, PJ, and Washabau, RJ. Treatment of severe immune-mediated thrombocytopenia with human IV immunoglobulin in 5 dogs. *J Vet Intern Med* 2007;21:261–265.
- Brooks, MB, and Catalfamo, JL. Platelet disorders and von Willebrand disease. In: Ettinger, SJ, Feldman, EC, eds. *Textbook of Veterinary Internal Medicine*, 6th ed., pp. 1918–1929. St Louis: Elsevier, 2005.
- Miller, MD, and Lunn, KF. Diagnostic use of cytologic examination of bone marrow from dogs with thrombocytopenia: 58 cases (1994–2004). *J Am Vet Med Assoc* 2007;231:1540–1544.
- Neel, JA, Birkenheuer, AJ, and Grindem, CB. Thrombocytopenia. In: Bonagura, JD, ed. *Kirk's Current Veterinary Therapy XIV*, pp. 281–287. St. Louis: Saunders, 2009.
- Rozanski, EA, Callan, MB, Hughes, D, Sanders, N, and Giger, U. Comparison of platelet count recovery with use of vincristine and prednisone or prednisone alone for treatment for severe immune-mediated thrombocytopenia in dogs. *J Am Vet Med Assoc* 2002;220:477–481.
- Scott, MA. Immune-mediated thrombocytopenia. In: Feldman, BF, Zinkl, JG, and Jain, NC, eds. *Schalm's Veterinary Hematology*, 5th ed., pp. 478–487. Philadelphia: Lippincott, 2000.

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Ivermectin Toxicity



DEFINITION/OVERVIEW

- Ivermectin and other macrolides, such as selamectin, doramectin, moxidectin, and milbemycin, are antiparasitic drugs that are effective against both external and internal parasites.
- In general, these drugs are commonly used, are very effective, and have wide margins of safety.
- Some collie-type breeds have a genetic mutation that causes them to develop neurotoxicity at low doses.
- In other breeds toxicity occurs only with severe overdose.
- This discussion refers to ivermectin but applies to other similarly acting macrolides.



ETIOLOGY/PATHOPHYSIOLOGY

- Ivermectin and other similarly acting drugs act as GABA agonists at the neuromuscular junction in the peripheral nervous system of nematode and arthropod parasites.
- GABA is an inhibitory neurotransmitter.
- In mammals, GABA-containing neurons are limited to the CNS where the blood-brain barrier protects them from exposure to many drugs, including ivermectin.
- The multiple drug resistance gene, MDR1, encodes for P-glycoprotein, a principal component of the blood-brain barrier. The mutation, *mmdr1-1Δ*, results in loss of P-glycoprotein function, and thereby allows access to the brain by ivermectin and some other drugs that are also substrates of P-glycoprotein. Dogs with this mutant allele are susceptible to ivermectin toxicity at low doses.

Systems Affected

- The toxic effect is on the neurologic system; other organ systems are affected indirectly.



SIGNALMENT/HISTORY

Genetic Basis

- Analysis of the history of the canine mutation shows that dogs carrying the mutant allele *mmdr1-1δ* are descendants of a dog that lived in Great Britain before 1873 and was one of the foundation dogs for a branch of working sheepdogs selected for show.
- Seven collie-type breeds and two sighthound breeds were identified as carrying this allele. These modern-day breeds are collie, Shetland sheepdog, old English sheepdog, McNab cattledog, Australian shepherd, miniature Australian shepherd, and English shepherd. Two other breeds of sighthound type but descended from the common ancestor are silken windhound and longhaired whippet.
- Within breeds, the frequency of the mutant allele varies from less than 4 percent in old English sheepdogs to more than 50 percent in collies.
- Ivermectin sensitivity has been reported in border collie, bearded collie, and Australian cattle dog. The mutant allele was not found in one study that included members of these breeds, indicating a low frequency of the allele or that another mutation is responsible.

Signs

- Toxicity is to the CNS with other systems affected secondarily.
- Ataxia
- Tremors
- Seizures
- Coma
- Death

Historical Findings

- Ivermectin toxicity should be considered in a dog belonging to a susceptible breed with a history of acute onset of neurologic signs combined with recent exposure to drugs in this group.
- In dogs with the mutant allele, doses of ivermectin of 100 to 500 µg/kg have caused toxicity.
- In other breeds, toxicity occurs only with severe overdoses (>2000 µg/kg) usually caused by miscalculation using equine or bovine preparations. The median lethal dose for experimental beagle dogs was 80,000 µg/kg.
- Exposure can also occur from dogs eating feces of treated large animals because the drug is eliminated in the feces.
- Young animals are more susceptible to toxicity because their blood-brain barrier is not fully developed.
- Toxicity has been reported in kittens at doses of 300 to 400 µg/kg.



CLINICAL FEATURES

Physical Examination

- Ataxia or recumbency and altered mental state (e.g., depression, obtundation) are the primary neurologic signs with stupor, coma, and even death occurring in severely affected dogs.
- Those with depressed mentation may also have decreased gag reflex.
- Muscle tremors, seizures, and loss of menace and pupillary light response may occur.
- Spinal cord reflexes may be normal or increased.
- Other signs include bradycardia, mydriasis, miosis, hypersalivation and vomiting.
- Clinical signs in dogs can range in severity, even with ingestion/exposure to similar doses.
- Onset of signs can be within a few hours after administration of a single dose.
- Animals being treated daily may develop signs of toxicity only after several days.



DIFFERENTIAL DIAGNOSIS

- Differentiation from other causes of acute onset neurologic signs is based on a history of exposure to the drug in a susceptible canine breed or severe overdose in other animals.



DIAGNOSTICS

Laboratory

- Ivermectin and other macrolides can be detected in serum, gastrointestinal contents, liver, and fat but levels in tissues do not correlate with toxicity because it is the concentration of the drug in the brain that determines toxicity.

Other

- Reversal of neurologic signs in response to the anticholinesterase physostigmine supports but does not confirm a diagnosis. Its use for this purpose is not recommended because of adverse side effects (see *Therapeutics*).
- A DNA-based test for the mutant genotype is available and could be used to confirm that a dog is at increased risk of toxicity.

Pathological Findings

- No specific lesions are directly caused by these drugs.



THERAPEUTICS

- The goals of therapy are decontamination and support.

Drug(s) of Choice

- There is no specific antidote.
- If the drug has been ingested in the past 2 hours emesis should be induced, provided that the patient is alert enough to protect its airway. If the patient is not able to protect its airway, orogastric lavage under general anesthesia with intubation should be performed.
- Orogastric lavage should be followed by activated charcoal and a sorbital cathartic. Repeat doses of activated charcoal are indicated because of the potential for enterohepatic recirculation.
- Anticholinesterase drugs have been administered as a diagnostic test or for short-term improvement of clinical signs. Physostigmine may result in partial improvement of signs but the effect lasts less than 1 hour. The potential toxicities of physostigmine are tremors, seizures, ptialism, lacrimation, urination, and defecation. It does not target ivermectin toxicity directly and is not recommended.
- Picrotoxin, a GABA antagonist, has also been used to treat ivermectin toxicity. Picrotoxin resulted in a rapid improvement in mental state followed by a seizure. Any improvement is likely to be transient, and it is not recommended because of the risk of adverse effects.
- If treatment for seizures or tremors is required it may be advisable to avoid the use of benzodiazepines, such as diazepam, because the binding sites for benzodiazepine, GABA, and ivermectin are closely associated. It has been proposed, but not proven that enhancement of the toxic effects might occur. Barbiturates may be preferable because their binding site in the brain is not as closely associated with the ivermectin binding site.

Supportive Care

- Patients should receive supportive care as appropriate for their clinical signs and must be closely monitored. Long-term intensive care nursing may be needed.
- Deterioration from the initial presenting signs for approximately the next 6 days followed by gradual improvement over the next 6 to 18 days is expected. Longer courses have been reported.
- Special attention should be paid to the respiratory and cardiovascular systems because hypoventilation that requires mechanical ventilation and bradycardia that requires treatment with an anticholinergic agent such as glycopyrrolate have been reported.
- Aspiration pneumonia due to a combination of recumbency and a decreased gag reflex can occur.
- Patients who are unable to eat and drink normally must receive fluid and electrolyte therapy and nutritional support. Oral intake of food or water should not be attempted

in patients with altered mental states because they may have decreased gag reflexes and be unable to properly protect their airway. In these patients, nasogastric or gastric tube feeding is preferred but intravenous nutrition may be preferred.

- Severely affected patients are recumbent and meticulous care for the recumbent patient is needed.



COMMENTS

Prognosis

- The prognosis for recovery without long-term sequelae is good even in severely affected patients provided that aggressive intensive care support is administered.

Abbreviations

- CNS: central nervous system
- GABA: gamma-amino butyric acid

Suggested Reading

- Hopper, K, Aldrich, J, and Haskins, SC. Ivermectin toxicity in 17 Collies. *J Vet Intern Med* 2002;16:89–94.
- Mealey, KL. Ivermectin: macrolide antiparasitic agents. In: Peterson, ME, ed. *Small Animal Toxicology*, 2nd ed., pp. 785–794. St. Louis: Elsevier Saunders, 2006.
- Mellema, MS, and Haskins, SC. Supportive care of the poisoned patient. In: Peterson, ME, ed. *Small Animal Toxicology*, 2nd ed., pp. 97–99. St. Louis: Elsevier Saunders, 2006.
- Neff, MW, Robertson, KR, Wong, AK, et al. Breed distribution and history of canine mmdr1-1δ, a pharmacogenetic mutation that marks the emergence of breeds from the collie lineage. *Proc Natl Acad Sci USA* 2004;101; 32:11725–11730.
- Scott, NE. Ivermectin toxicity. In: Silverstein, DC, and Hopper, K, eds. *Small Animal Critical Care Medicine*, pp. 392–394. St. Louis: Elsevier Saunders, 2008.

Author: Janet Aldrich

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Allan J Paul

Lily Toxicity



DEFINITION/OVERVIEW

- Lily toxicity causes acute nephrotoxicity in cats.



ETIOLOGY/PATHOPHYSIOLOGY

- A variety of *Lilium* and *Heimerocallis* lily species (Figures 57.1 and 57.2) have been associated with nephrotoxicity, including Easter lily (*Lilium longiflorum*), tiger lily (*L. tigrinum*), asiatic hybrid lily (*Lilium* sp.), day lily (*Heimerocallis dumortirei*, *H. fulva*), early day lily (*H. sieboldii*), orange day lily (*H. graminea*), red lily (*L. umbellatum*), rubrum lily (*L. speciosum rubrum*), stargazer lily (*L. orientalis*), western lily (*L. umbellatum*), and wood lily (*L. umbellatum*). Both the leaves and flowers are toxic, although the flowers seem more toxic. The toxic principle is water soluble.

Systems Affected

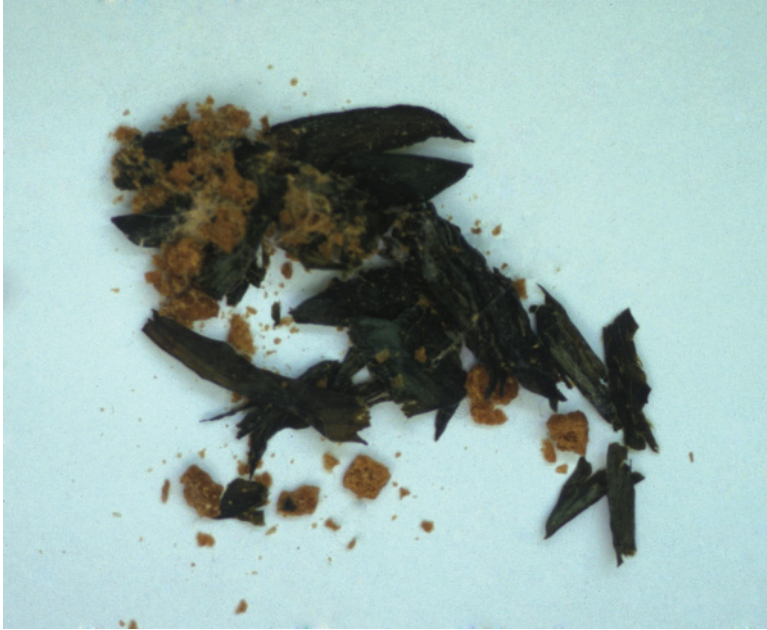
- Renal/Urologic—The predominant component of lily toxicity is acute tubular nephrosis that causes acute renal failure. Azotemia is apparent within 24 hours of ingestion.
- Gastrointestinal—Vomiting is a common occurrence within hours of ingestion. Pancreatitis and pancreatic lesions can occur within 8 hours of ingestion.
- Nervous—Seizures may occur as early as 8 hours after ingestion.
- Hepatobiliary—Liver enzyme elevations have been reported in later stages of disease.
- Musculoskeletal—Increased creatine kinase was noted in experimental cases, but no histologic lesions were seen in muscle tissue.



■ **Figure 57.1** Easter lily plant.



■ **Figure 57.2** Day lily plant.



■ **Figure 57.3** Lily plant leaves that were vomited.



SIGNALMENT/HISTORY

- Lily toxicity affects cats. Dogs that ingest lily plants have mild, short-term gastroenteritis without renal failure.

Historical Findings

- Vomiting, anorexia, and lethargy are usually the initial signs, and appear within 1 to 5 days after ingestion. The initial gastrointestinal signs may resolve, followed by signs of uremia. Polyuria may occur as early as 12 hours after ingestion. Neurologic signs of ataxia, depression, tremors, and seizures have been reported.
- Owners may find parts of the plant in vomitus, or evidence that the plant has been chewed (Figure 57.3).



CLINICAL FEATURES

- Dehydration, renal pain, and renomegaly are common findings on initial examination. Mentation may vary from bright and alert to comatose. Urine output varies from anuric to polyuric; overhydration is common in anuric cats shortly after starting fluid therapy. Fever has been reported in some cases.



DIFFERENTIAL DIAGNOSIS

- Initial gastrointestinal signs (vomiting, anorexia)
 - Nonspecific gastroenteritis
 - Dietary indiscretion
 - Pancreatitis
- Acute uremia in cats
 - Nephrotoxins (e.g., ethylene glycol, NSAIDs, aminoglycosides)
 - Ureteral obstruction
 - Pyelonephritis
 - Lymphosarcoma
 - Recent ischemic events (i.e., anesthesia, hypovolemia, hypotension)



DIAGNOSTICS

Complete Blood Count/Biochemistry

- Azotemia: elevated BUN and creatinine with elevated phosphorus
- Hyperkalemia (common) or hypokalemia
- Metabolic acidosis, elevated anion gap
- Variable increased creatine kinase: decreases within a few days
- Alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase: increased in later stages
- Occasionally hypocalcemia

Urinalysis

Consistent with acute tubular nephrosis

- Isothenuria
- Glucosuria
- Proteinuria
- Granular casts

Pathological Findings

- The kidneys are usually swollen and may have perirenal edema. Histologically, acute tubular nephrosis that affects predominantly the proximal tubule is characteristic, frequently with evidence of epithelial regeneration. Small numbers of birefringent crystals are occasionally seen, but lily toxicity is not caused by oxalate nephrosis.
- Pancreatic degeneration in early stages and fibrosing pancreatitis in late stages have been reported. Hepatic and lung congestion may occur.



THERAPEUTICS

Therapeutic objectives

- Gastric decontamination to limit absorption of toxic components.
- Early aggressive fluid treatment to counteract dehydration from polyuria and possibly to increase elimination of toxic component prior to onset of renal failure.
- Standard therapy to manage acute renal failure.
- Treatment with fluid therapy is important even if clinical signs are not present. Peace lily (*Spathiphyllum* spp.) and lily-of-the-valley (*Convallaria majalis*) are not true lilies and do not cause nephrotoxicity.

Drug(s) of Choice

- Induce vomiting: apomorphine (administered via conjunctival sac or 0.03–0.04 mg/kg IV), 3% hydrogen peroxide (0.25–0.5 ml/kg PO), or xylazine (0.44 mg/kg IV, IM, or SQ)
- Activated charcoal: 1 to 4 g/kg PO (protect airway with cuffed endotracheal tube if patient is unconscious)
- Fluid therapy: balanced polyionic crystalloid (i.e., lactated Ringer's solution or plasmalyte-147) or saline IV at twice the maintenance rate for 48 hours prior to onset of renal failure

Precautions/Interactions

- If urine production is decreased, aggressive diuresis will result in volume overload.

Alternative Drugs

- If medical management does not control uremia, hemodialysis or peritoneal dialysis has been used with favorable outcomes.

Diet

- Anorexia is common and may require placement of a feeding tube for management. A moderately protein restricted diet is appropriate.



COMMENTS

Client Education

- If renal failure resolves completely (or does not develop), no special care is needed after discharge. If residual renal damage persists, standard care for chronic kidney disease will be required.

Patient Monitoring

- Early treatment: Assessment of BUN, creatinine, electrolytes, and phosphorus at admission and after 48 hours of fluid therapy is recommended.
- After onset of renal failure: Monitoring as for any cause of acute renal failure. Particular attention to volume status because many cats develop oliguria or anuria.

Prevention/Avoidance

- Lily plants should not be available in the cat's environment. Lilies are common in floral arrangements, and day lilies are common in gardens.

Expected Course and Prognosis

- Early treatment (within 18 hours of ingestion): Prompt decontamination and fluid therapy may prevent renal failure and has a good prognosis
- After development of renal failure: Overall mortality rates for cats with acute renal failure from nephrotoxic causes are about 50 to 60 percent. Cats that survive the acute phase may recover completely or have residual chronic kidney disease.

Abbreviations

- BUN: blood urea nitrogen
- IM: intramuscularly
- IV: intravenously
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- SQ: subcutaneously

See Also

- Acute Renal Failure

Suggested Reading

- Berg, RIM, Francey, T, and Segev, G. Resolution of acute kidney injury in a cat after lily (*Lilium lancifolium*) intoxication. *J Vet Intern Med* 2007;21:857–859.
- Hall, JO. Lily nephrotoxicity. In: August, JR, ed. *Consultations in Feline Internal Medicine*, 4th ed., pp. 308–310. Philadelphia: W.B. Saunders, 2001.
- Langston, CE. Acute renal failure caused by lily ingestion in six cats. *J Amer Vet Med Assoc* 2002; 220(1):49–52.
- Rumbeiha, WK, Francis, JA, Fitzgerald, SD, et al. Comprehensive study of Easter lily poisoning in cats. *J Vet Diagn Invest* 2004;16:527–541.

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Lower Urinary Tract Infection (UTI)



DEFINITION/OVERVIEW

- Lower UTI encompasses a wide variety of clinical entities whose common denominator is microbial invasion of the bladder (cystitis), urethra (urethritis), prostate gland (prostatitis), or two or more of these sites.
- Bacteriuria—refers to the presence of bacteria in urine. Identification of bacteria in urine is not synonymous with UTI because they may represent contaminants. *Significant bacteriuria* is a term used to denote bacteriuria that represents UTI. A large number of bacteria in a properly collected and cultured urine specimen is indicative of UTI. Small numbers of bacteria in urine obtained from untreated patients usually indicate contamination. *Asymptomatic bacteriuria* is defined as significant bacteriuria that is unaccompanied by clinical signs.
- Uncomplicated UTI—defined as an infection in which no underlying structural or functional abnormality of the urinary system can be identified. Most uncomplicated UTIs are likely to be caused by transient, self-limiting, and potentially reversible abnormalities of host defenses.
- Complicated UTI—occur secondary to identifiable diseases that interfere with normal host defenses.
- Recurrent UTI—*Relapses* (persistent UTIs) are recurrences caused by the same species and strain of microorganism within several weeks of the date of cessation of antimicrobial therapy. *Reinfections* are recurrent UTIs caused by a different organism.
- Superinfections—Superinfection is defined as infection with an additional organism during the course of antimicrobial therapy.



ETIOLOGY/PATHOPHYSIOLOGY

- Usually caused by ascending migration of aerobic bacteria from the intestinal and lower genitourinary tract into the lower urinary tract under conditions that permit bacteria to persist in urine or adhere to urothelium and subsequently multiply.
- Any disease process or therapeutic manipulation that interferes with normal micturition, alters structural or functional characteristics of the urinary bladder or urethra, alters the volume or composition of urine, or impairs immune responsiveness predisposes the urinary tract to bacterial colonization.

- Aerobic bacteria are the most common uropathogens; *Escherichia*, *Staphylococcus*, and *Proteus* spp. (account for over half of all cases); *Streptococcus*, *Klebsiella*, *Enterococcus*, *Pseudomonas*, and *Corynebacterium* spp. also common
- Approximately 72 percent of UTIs in dogs are caused by a single species of bacteria, 20 percent are caused by two species, and 8 percent are caused by three or more species.
- Anaerobic bacteria, fungal agents, parasites, viruses, mycoplasmas, and ureaplasmas are uncommon causes in dogs and cats.

Systems Affected

- Renal/Urologic—lower urinary tract

Risk Factors/Causes

- Common in female dogs; less common in male dogs, uncommon in cats.
- Risk of UTI in cats increases with increasing age.
- Increased risk associated with prolonged urinary catheterization, perineal urethrotomies, long-term corticosteroid administration, hyperadrenocorticism, and diabetes mellitus.

Historical Findings

- None in some patients (asymptomatic UTI)
- Pollakiuria
- Dysuria
- Hematuria
- Malodorous urine
- Periuria—urination in inappropriate locations
- Urge incontinence—apparent loss of ability to voluntarily control urination



CLINICAL FEATURES

- May be clinically normal.
- Acute infection—bladder may be small and painful; palpation may induce urination.
- Chronic infection—bladder or urethral wall may be thickened; masses may be palpable.
- Other predisposing anatomic or functional abnormalities associated with complicated UTIs may be identified.



DIFFERENTIAL DIAGNOSIS

Dogs

- Uroliths
- Neoplasia (benign and malignant)

- Trauma
- Neurogenic disorders including reflex dyssynergia, urethral spasm, and hypotonic or atonic bladder (primary or secondary).
- Iatrogenic disease including due to urethral catheterization, indwelling urethral catheters (especially open systems), postsurgical catheters, and urethrostomy complications.
- Anatomic abnormalities including urachal anomalies and acquired urethral strictures.
- Behavioral disorders resulting in periuria.

Cats

- Idiopathic lower urinary tract disease
- Uroliths and urethral plugs
- Behavioral disorders resulting in periuria
- Neoplasia (benign and malignant)
- Trauma
- Neurogenic disorders including reflex dyssynergia, urethral spasm, and hypotonic or atonic bladder (primary or secondary).
- Iatrogenic disease including due to urethral catheterization, indwelling urethral catheters (especially open systems), postsurgical catheters, reverse-flushing solutions, and urethrostomy complications.
- Anatomic abnormalities including urachal anomalies and acquired urethral strictures.



DIAGNOSTICS

- Results of CBC and serum biochemistries are usually normal.
- Urine sediment should be evaluated by microscopic techniques; dipstick leukocyte and bacteria test pads are unsatisfactory for canine and feline urine specimens; staining of urine sediment with Wright's, Gram's, or new methylene blue stain may significantly improve detection of bacteriuria.
- Pyuria—Commonly associated with UTI but may occur with inflammation that is due to other noninfectious causes (e.g., uroliths); absence does not rule out UTI because it may occur without an inflammatory response.
- Hematuria and proteinuria—Commonly associated with UTI but may be associated with other inflammatory and noninflammatory disease processes; absence does not rule out UTI because it may occur without an inflammatory response.
- Bacteriuria—presence of bacteria in urine; commonly associated with UTI but may represent specimen contamination during collection or storage or misinterpretation of nonbacterial look-alikes in urine sediment; absence does not rule out UTI because large numbers of bacteria are required for visualization by light microscopy.
- Diagnostic quantitative urine culture and sensitivity testing
 - Necessary for definitive diagnosis are isolation and identification of bacteria, quantification of the number of bacteria (cfu) per mL of urine, and determination of the organism's susceptibility to antimicrobial agents.

- Proper collection, storage, and handling of urine specimens are important for interpretation of culture results; cystocentesis is generally the preferred method of collection; antimicrobics should be discontinued for 3 to 5 days before diagnostic urine culture; urine may be refrigerated in sterile closed container for up to 8 hours without substantial changes in results; commercially manufactured collection tubes containing preservatives combined with refrigeration may be used to preserve specimens for up to 72 hours.
- Quantification of bacteria in a urine sample allows differentiation between harmless bacterial contaminants of urine and pathogenic organisms causing UTI. Detection of greater than 1,000 cfu/mL of urine collected by cystocentesis is considered significant bacteriuria in dogs and cats and indicates the probability of UTI. In urine samples collected by voluntary micturition or manual compression of the urinary bladder, detection of greater than 100,000 cfu/mL of urine in dogs and 10,000 cfu/mL of urine in cats is consistent with UTI. However, studies in normal dogs and cats have shown that contamination of voided urine samples may result in colony counts of greater than 100,000/mL. Consequently, voided urine samples are generally unsatisfactory for routine diagnostic bacterial culture. In addition, other factors may influence the results of quantitative cultures of urine including, species, collection method, time elapsed between collection and culture, method of preservation, in vivo growth characteristics of the bacteria, frequency or micturition, magnitude of diuresis, site(s) of infection, and administration of antimicrobics prior to bacterial culture.
- In vitro susceptibility testing that determines the MIC of each drug against the bacterial isolate is the preferred method of identifying appropriate antimicrobics. Any antimicrobial whose urine concentration is at least four times the MIC of the bacterial isolate is likely to be effective.
- Aerobic culture of bladder wall biopsy specimens may detect UTI in patients with negative urine cultures.
- Survey and contrast radiographic and ultrasonic evaluations of the lower urinary tract may exclude other causes of lower urinary tract signs and identify predisposing factors (e.g., neoplasia) or sequelae (e.g., infection-induced struvite uroliths). Rarely intramural gas formation may be observed (emphysematous cystitis).
- Urethrocystoscopy may exclude other causes of lower urinary tract signs and identify predisposing factors or sequelae.
- Biopsies obtained with urinary catheters, cystoscopes, or via surgery may permit morphologic characterization of the inflammatory or neoplastic lesions; not routinely needed.

Pathologic Findings

- Varying degrees of mucosal ulceration and submucosal edema, vasodilation, hemorrhage, and inflammatory cell infiltration are common light microscopic lesions observed in urinary bladders of patients with acute and chronic bacterial cystitis.

- Follicular cystitis—a common form of chronic cystitis characterized by multifocal grey-white mucosal nodules often surrounded by a zone of hyperemia; nodules are composed of proliferating aggregations of lymphocytes.
- Polypoid cystitis—an uncommon form of chronic cystitis characterized by mononuclear cell infiltration, epithelial proliferation, and development of villus-like sessile polyps.
- Granulomatous (proliferative cystitis)—an uncommon form of chronic urethritis resulting in partial or complete urethral obstruction; lesions are generally characterized by severe, extensive, lymphocytic or chronic suppurative inflammation with granulation tissue and edema.



THERAPEUTICS

- Therapeutic goals are to eliminate bacteria from urine and tissues and allow the urinary tract and its defense mechanisms time to recover sufficient function to prevent recurrence.
- Patients with uncomplicated lower UTI are typically managed as outpatients; diagnostic evaluation may require brief hospitalization.
- Predisposing abnormalities in host defenses should be eliminated or controlled.
- Antimicrobial should be selected on the basis of antimicrobial susceptibility testing, their ability to achieve high concentrations in urine, ease of administration, relative cost, and safety.
- Antimicrobial are most effective when administered every 8 hour; however, fluoroquinolones and trimethoprim-sulfa products are effective when administered every 12 hour.
- Acute uncomplicated bacterial UTI may be treated empirically without results of susceptibility testing provided that patients have not had frequent or recurrent signs and have not been given antimicrobial drugs in the past 4 to 6 weeks; a 10- to 14-day course is usually effective.
- Results of susceptibility testing are essential for patients with a complicated UTI, a history of recurrent or persistent signs, prior antimicrobial therapy, or recent catheterization, or who are at high risk for morbidity (e.g., uremia, urinary outflow obstruction).
- Chronic or complicated UTI resulting from an identifiable disease that impairs host defenses (e.g., diabetes mellitus) should be treated for 4 to 6 weeks; however, some patients may require longer treatment to eradicate infection.
- Long-term low-dose antimicrobial therapy can be used to prevent UTIs in patients with frequent reinfections. Prophylactic antimicrobial therapy is started immediately after eradication of the most recent episode of UTI using conventional therapy. Generally, the same antimicrobial that successfully eradicated the latest episode of UTI is used for long-term prophylactic therapy. The antimicrobial dose is reduced to one half to one-third the normal total daily dose given every 24 hours at bedtime after the animal has urinated; continue therapy for 6 months.

Drug(s) of Choice

- Ampicillin 25 mg/kg PO every 8 hours
- Amoxicillin 11 mg/kg PO every 8 hours
- Amoxicillin/clavulanate 10 to 20 mg/kg every 8 hours
- Tetracycline 20 mg/kg PO every 8 hours
- Trimethoprim-sulfadiazine 15 mg/kg combined PO every 12 hours
- Cephalexin 30 mg/kg PO every 8 hours
- Enrofloxacin 2.5 mg/kg PO every 12 hours

Precautions/Interactions

- Specific antimicrobial drugs are contraindicated in patients with known hypersensitivity to them.
- Trimethoprim-sulfa products have been associated with keratoconjunctivitis sicca, hepatitis, hepatic necrosis, anemia, granulocytopenia, and polyarthritis in dogs; use with caution in patients with pre-existing hepatic disease.
- Enrofloxacin has been associated with retinal degeneration in cats treated with high doses.
- Tetracyclines may cause discoloration of teeth in young animals; avoid coadministration with food especially dairy products; use with caution in patients with pre-existing renal or hepatic disease.
- Because of potential nephrotoxicity associated with long-term administration of aminoglycosides, alternative safer antimicrobics should be selected whenever possible; use with extreme caution in patients with pre-existing renal disease.

Alternative Drugs

- Chloramphenicol 33 mg/kg PO every 8 hours
- Nitrofurantoin 4 mg/kg PO every 6 to 8 hours
- Amikacin 15 to 20 mg/kg SQ, IM, or IV every 24 hours
- Imipenem/Cilastatin 5 to 10 mg/kg SQ or IV every 8 hours

Diet

- Dietary modification may be indicated for management of other concurrent urinary tract disorders (e.g., urolithiasis).

Surgical Considerations

- Only indicated for detection or correction of abnormalities predisposing to UTI



COMMENTS

Client Education

- Clinical improvement can be expected in 24 to 48 hours after initiating appropriate therapy; however, compliance with treatment recommendations is essential to allow

adequate time for host urinary tract defenses to heal and regain sufficient function to prevent recurrence.

- Prognosis for simple uncomplicated UTI is generally good to excellent.
- Prognosis for complicated UTI depends on the nature of the infecting organism (virulence and antimicrobial susceptibility) and the ability to identify and correct or control predisposing abnormalities of host defenses.
- Compliance with recommendations for treatment and follow-up is crucial for optimal results.

Patient Monitoring

- Therapeutic urine culture—Culture of urine at strategic times during antimicrobial therapy (so-called therapeutic cultures) is an effective method of assessing therapy, especially in patients with a high risk of morbidity or mortality associated with their UTI or in patients receiving potentially toxic antimicrobics. Therapeutic cultures allow timely testing of antimicrobial efficacy, verification of proper antimicrobial drug administration, early detection of emerging bacterial resistance, timely detection of persistent infections, and provision of justification for early discontinuation of potentially toxic antimicrobial. Initial response to therapy is considered effective only if culture of a properly collected urine sample does not result in growth of bacteria. Therapeutic urine cultures are typically performed 3 to 5 days after initiation of antimicrobial therapy, 3 to 5 days before scheduled discontinuation of therapy, or anytime clinical signs or laboratory abnormalities recur during therapy.
- Surveillance urine culture—After antimicrobial therapy, timely follow-up evaluations (so-called surveillance cultures) are indicated to confirm eradication of the UTI and to detect recurrent infections at a subclinical state. Surveillance cultures are essential to differentiate relapses from reinfections. Urine collected by cystocentesis should be cultured 7 to 10 days after completing antimicrobial therapy to confirm successful eradication and identify relapses. Urine culture may be performed at 1 to 2 months and 3 to 6 months after completion of therapy to detect reinfections. Patients receiving long-term low-dose prophylactic antimicrobial therapy should have a culture of urine collected by cystocentesis every 1 to 2 months.
- Urine culture and urinalysis should be performed anytime clinical signs recur.

Prevention/Avoidance

- Identify and eliminate or control predisposing abnormalities of host defenses.
- Avoid indiscriminate use of urinary catheters.
- Avoid surgical procedures that permanently alter host defenses (e.g., perineal urethrostomies).
- Consider long-term low-dose prophylactic antimicrobial therapy in patients with frequent reinfections.

Possible Complications

- Struvite urolithiasis—UTI with urease-producing microbes (*Staphylococcus*, *Proteus*, *Klebsiella*, *Pseudomonas*, *Corynebacterium*, and *Ureaplasma* spp.)
- Polypoid cystitis—uncommon; may be associated with chronic bacterial UTI

- Emphysematous cystitis—uncommon; associated with infection with gas-producing microbes
- Granulomatous (proliferative) urethritis—uncommon; may be associated with chronic bacterial UTI
- Pyelonephritis, prostatitis, diskospondylitis, endocarditis, or sepsis

Expected Course and Prognosis

- Untreated UTIs persist indefinitely and may be associated with an increased risk for urolithiasis and bacterial invasion of other components of the urinary system (e.g., the kidneys) or tissues outside the urinary tract.
- Clinical signs typically improve within 24 to 48 hours after initiation of appropriate therapy; persistent signs may be due to treatment failure or the presence of other concurrent lower urinary tract disorders that cause similar signs (e.g., uroliths).
- Prognosis for simple uncomplicated UTI is generally good to excellent.
- Prognosis for complicated UTI depends on the nature of the infecting organism (virulence and antimicrobial susceptibility) and the ability to identify and correct or control predisposing abnormalities of host defenses.

Synonyms

- Bacterial cystitis
- Urethrocystitis
- Urethritis

Abbreviations

- CBC: complete blood count
- cfu: colony forming unit
- MIC: minimum inhibitory concentration
- IM: intramuscularly
- IV: intravenously
- PO: by mouth
- SQ: subcutaneously
- UTI: urinary tract infection

Suggested Reading

- Bartges, JW, and Barsanti, JA. Bacterial urinary tract infections in cats. In: Bonagura, JD, ed. *Kirk's current veterinary therapy XIII*, 13th ed., pp. 880–882. Philadelphia: Saunders, 2000.
- Ling, GV. Bacterial infections of the urinary tract. In: Ettinger, SJ, and Feldman, EC, eds. *Textbook of veterinary internal medicine*, 5th ed., pp. 1678–1686. Philadelphia: Saunders, 2000.
- Senior, DF. Management of difficult urinary tract infections. In: Bonagura, JD, ed. *Kirk's current veterinary therapy XIII*, 13th ed., pp. 883–886. Philadelphia: Saunders, 2000.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: George E. Lees

Macadamia Nut Toxicity



DEFINITION/OVERVIEW

- Syndrome of tremors, weakness, agitation, vomiting, diarrhea, and paralysis in dogs associated with ingestion of macadamia nuts.
- Clinical signs can develop when 2.4 to 62.4g/kg of macadamia nuts have been ingested.
- Clinical signs can develop within 12 hours of ingestion.
- No case fatalities have been reported.



ETIOLOGY/PATHOPHYSIOLOGY

- Mechanism of toxicity unknown.

Systems Affected

- Gastrointestinal—Vomiting and diarrhea, often with visible macadamia nuts in the vomitus or stool
- Nervous system—Tremors, ataxia, weakness, ascending paralysis (primarily rear limbs)



SIGNALMENT/HISTORY

- Dogs

General Comments

- Witnessed ingestion of macadamia nuts
- Chewed up packages that contained macadamia nuts

Historical Findings

- Vomiting or diarrhea, often with macadamia nuts visible in the vomitus
- Ataxia

- Tremors
- Muscle weakness
- Ascending paralysis
- Hyperthermia

Physical Examination Findings

- Ataxia, tremors, lower motor neuron signs to rear limbs, muscle weakness, paralysis, diarrhea, vomitus staining on muzzle, hyperthermia when severe tremors have occurred

Risk Factors/Causes

- Iatrogenic administration of macadamia nuts to dogs
- Access to macadamia nuts
- Free roaming
- Ingestion of macadamia nuts
- Toxic principle unknown



DIFFERENTIAL DIAGNOSIS

- Botulism
- Coonhound paralysis (polyradiculoneuritis)
- Tick paralysis
- Intervertebral disk disease
- Metaldehyde toxicity
- Mycotoxin ingestion
- Mushroom toxicity
- Seizures, idiopathic epilepsy
- Gastrointestinal
- Viral or bacterial gastroenteritis
- Pancreatitis
- Gastrointestinal parasitism
- Hypoadrenocorticism



DIAGNOSTICS

Complete Blood Count

- Serum biochemistry: Elevated lipase
- Urinalysis: Normal



THERAPEUTICS

- Induce emesis within 3 hours of ingestion (apomorphine 0.03–0.04 mg/kg IV).
- Supportive care with intravenous crystalloid fluids to maintain hydration, turn frequently to prevent decubital ulcer formation, passive range of motion exercises, placement of a urinary catheter to maintain cleanliness, antiemetics to decrease vomiting and risk of aspiration pneumonia

Drug(s) of Choice

- Antiemetics
 - Metoclopramide 1 to 2 mg/kg per day IV CRI, PO
 - Cerenia (1 mg/kg SQ, 2 mg/kg PO)
 - Dolasetron (0.6 mg/kg IV every 24 hours)
 - Ondansetron (1 mg/kg IV every 8–12 hours)
- Treat tremors
 - Methocarbamol (45–220 mg/kg IV slowly to effect; not to exceed 220 mg/kg IV)
 - Guaifenesin (44–110 mg/kg IV)
 - Diazepam (0.5–2 mg/kg IV to effect)

Expected Course and Prognosis

- No reported deaths attributed to macadamia nut toxicity
- Very favorable if vomiting is induced within 2 to 3 hours of ingestion, followed by activated charcoal
- Will recover within 24 to 48 hours of onset of clinical signs

Suggested Reading

Cope, RB. Four new small animal toxicoses. *Aust Vet Pract* 2004;34(3):121–123.

Hansen, SR. Macadamia nut toxicosis in dogs. *Vet Med* 2002;274–276.

Hansen, SR, Buck, WB, Meerdink, G, and Khan, SA. Weakness, tremors and depression associated with macadamia nuts in dogs. *Vet Hum Toxicol* 2000;42(10):18–21.

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Magnesium Disorders



DEFINITION/OVERVIEW

- Hypomagnesemia
 - Dogs—serum magnesium <1.89 mg/dL and ionized magnesium <0.43 mmol/L.
 - Cats—serum magnesium <1.9 mg/dL and ionized magnesium <0.43 mmol/L.
- Hypermagnesemia
 - Dogs—serum magnesium >2.51 mg/dL and ionized magnesium >0.60 mmol/L.
 - Cats—serum magnesium >2.6 mg/dL and ionized magnesium >0.70 mmol/L.



ETIOLOGY/PATHOPHYSIOLOGY

- Magnesium is the second most abundant intracellular cation. The vast majority of magnesium is found in bone (60 percent) and muscle (20 percent). Less than 1 percent of total body magnesium is present in the serum.
- Because greater than 99 percent of total body magnesium is located in the intracellular compartment, serum magnesium concentrations do not always reflect total body magnesium status. Therefore, a normal serum magnesium concentration can occur in the presence of a total body magnesium deficiency.
- In the serum, magnesium exists in three distinct fractions: a protein-bound fraction (30 percent), an anion-complexed fraction (5 percent), and an ionized fraction (65 percent). The ionized fraction is thought to be the physiologically active component.
- Ionized magnesium appears to equilibrate rapidly across the cell membrane; thus extracellular ionized magnesium concentrations may be a more accurate indicator of intracellular stores.
- Magnesium is a coenzyme for the membrane-bound sodium-potassium ATPase pump and functions to maintain the sodium-potassium gradient across all membranes; as a result, it plays an important role in the activity of electrically excitable tissues.
- Interference with the electrical gradient can alter resting membrane potential, signal transduction, and smooth muscle tone, resulting in cardiovascular abnormalities such as arrhythmias and inappropriate vascular tone.
- Magnesium decreases acetylcholine release from nerve terminals and depresses the excitability of nerve and muscle membranes. Therefore, hypermagnesemia results in

hyporeflexia and flaccid paralysis and hypomagnesemia can result in muscle fasciculations and seizures.

- Magnesium regulates calcium movement into smooth muscle cells and can affect peripheral vascular tone and contractile strength.
- Because magnesium is necessary for the movement of sodium, potassium, and calcium into and out of cells, other manifestations of hypomagnesemia include metabolic abnormalities such as concurrent hypokalemia (often refractory to potassium supplementation), hyponatremia, and hypocalcemia.
- The renal system is the main regulator of serum magnesium concentration and total body magnesium content; any condition or disease that lowers glomerular filtration rate can cause hypermagnesemia.
- Hypomagnesemia causes resistance to the effects of PTH and increases the uptake of calcium into bone.
- The incidence of hypomagnesemia in dogs ranges from 6 to 54 percent, with the higher incidence rates occurring in critically ill dogs.
- The incidence of hypomagnesemia in cats has been reported to be 28 percent in a population of cats admitted to an intensive care unit.
- The incidence of hypermagnesemia in dogs has been reported to be 13 percent in a population of dogs admitted to a critical care unit. These dogs were 2.6 times more likely to not survive their illness when compared to dogs with normal serum magnesium concentrations.
- The incidence of hypermagnesemia in cats has been reported to be 17.5 percent in a population of cats admitted to an intensive care unit.

Systems Affected

- Endocrine/Metabolic
 - Hypomagnesemia—concurrent hypokalemia, hyponatremia, or hypocalcemia.
- Musculoskeletal
 - Hypomagnesemia and hypermagnesemia—weakness.
- Cardiovascular
 - Hypomagnesemia—arrhythmias (i.e., atrial fibrillation, supraventricular tachycardia, premature ventricular contractions, ventricular tachycardia, torsades de pointes, and ventricular fibrillation), hypertension, coronary artery vasospasm, and platelet aggregation.
 - Hypermagnesemia—arrhythmias (i.e., bradycardia, complete heart block, and asystole), hypotension, and hypothermia.
- Neuromuscular
 - Hypomagnesemia—hyperreflexia, muscle fasciculations, seizures, ataxia, and coma.
 - Hypermagnesemia—hyporeflexia and flaccid paralysis.
- Gastrointestinal
 - Hypomagnesemia and hypermagnesemia—dysphagia secondary to esophageal weakness.

- Respiratory
 - Hypomagnesemia and hypermagnesemia— hypoventilation and subsequent hypoxemia secondary to respiratory muscle weakness or paralysis.



SIGNALMENT/HISTORY

- No breed, age, sex, or genetic predilection.
- Signs associated with hypomagnesemia include lethargy, depression, weakness, tachyarrhythmias, hyperreflexia, muscle fasciculations, and seizures.
- Signs associated with hypermagnesemia include lethargy, depression, weakness, hypotension, bradycardia, hyporeflexia, flaccid paralysis, nausea, vomiting, and respiratory depression.

Risk Factors/Causes

- Hypomagnesemia—administration of magnesium-deplete intravenous fluids, total parenteral nutrition, or partial parenteral nutrition; administration of drugs that can increase renal magnesium loss including digitalis, diuretics, aminoglycosides, cisplatin, or cyclosporine; inflammatory bowel disease, lactation, diabetic ketoacidosis, pancreatitis, sepsis, shock, peritoneal dialysis, renal transplantation, and massive blood transfusion.
- Hypermagnesemia—renal failure, hypoadrenocorticism, massive hemolysis, iatrogenic overdose of magnesium supplementation, thoracic neoplasia with pleural effusion, and excessive use of magnesium-containing cathartics, laxatives, or antacids, especially in patients with underlying renal disease.

Historical Findings

- Hypomagnesemia and hypermagnesemia—frequently are nonspecific (i.e., lethargy, depression, weakness).



CLINICAL FEATURES

- Hypomagnesemia—weakness, tachyarrhythmia, hyperreflexia, or muscle fasciculations.
- Hypermagnesemia—weakness, nausea, hyporeflexia, flaccid paralysis, poor pulse quality, bradycardia, or respiratory depression.



DIFFERENTIAL DIAGNOSIS

- Signs of hypomagnesemia and hypermagnesemia are often vague and multisystemic.

- Hypomagnesemia—other electrolyte abnormalities such as hypocalcemia, hypokalemia, and hyperkalemia; primary cardiac disease, seizure disorders, and intoxications.
- Hypermagnesemia—gastrointestinal disease, neuromuscular disease, renal disease, cardiac disease, intoxications, and other electrolyte disorders such as hyperkalemia.



DIAGNOSTICS

- Indications for determining magnesium status are the presence of clinical signs associated with hypomagnesemia or hypermagnesemia, and the presence of disease processes, which may lead to alterations in total body magnesium concentrations.
- Determination of serum and/or ionized magnesium concentrations are most commonly done to determine magnesium status. Ionized magnesium concentrations are preferred over serum concentrations because ionized magnesium is thought to be the physiologically active component of the electrolyte and a more accurate indicator of intracellular magnesium stores.
- If serum or ionized magnesium concentrations are not routinely measured, the presence of hypokalemia, hyponatremia, or hypocalcemia may indicate concurrent hypomagnesemia, especially if the patient's hypokalemia is refractory to potassium supplementation.
- Alternate methods of evaluating magnesium status may include mononuclear blood cell magnesium concentrations or quantifying retention of a loading dose of magnesium. Human studies suggest that retention of greater than 40 to 50 percent of an administered magnesium load indicates total body magnesium depletion, whereas retention of less than 20 percent indicates adequate magnesium stores. (These tests are rarely done in veterinary medicine.)
- Urinary magnesium determination may help differentiate abnormalities associated with urinary magnesium loss from diseases of decreased intake, gastrointestinal loss, or alterations in magnesium distribution within the body.
- Electrodiagnostics (e.g., electrocardiography and electromyelography) may reveal the effects of hypomagnesemia or hypermagnesemia but will not help differentiate the cause.



THERAPEUTICS

- Hypomagnesemia—correct underlying problem, supplement magnesium, and discontinue drugs that cause renal magnesium loss.
- Hypermagnesemia—correct underlying problem, discontinue magnesium containing medications and nutritional supplements, diurese and promote renal magnesium excretion, support patient's cardiopulmonary system, and antagonize the effects of magnesium.

Drug(s) of Choice

- Hypomagnesemia
 - For rapid repletion of serum magnesium concentrations, magnesium chloride or magnesium sulfate can be administered IV in normal saline or 5% dextrose in water by continuous rate infusion at 0.75 to 1.0 mEq/kg per day for the first 24 to 48 hours.
 - A lower dose of 0.3 to 0.5 mEq/kg per day can then be used for an additional 3 to 5 days, if needed.
 - For the treatment of life-threatening ventricular arrhythmias, a dose of 0.15 to 0.3 mEq/kg of magnesium diluted in normal saline or 5% dextrose in water can be slowly administered IV over 5 to 15 minutes.
 - In stable patients with mild hypomagnesemia, magnesium chloride, magnesium gluconate, magnesium oxide, or magnesium hydroxide can be administered orally at a dose of 1 to 2 mEq/kg every 24 hours.
- Hypermagnesemia
 - Diurese with 0.9% NaCl at 2 to 4 ml/kg per hour IV.
 - Furosemide at 1 to 4 mg/kg every 8 to 12 hours PO, SQ, IM, or IV to increase renal magnesium excretion.
 - Calcium gluconate at 50 mg/kg IV over 15 to 30 minutes to antagonize the effects of magnesium at the neuromuscular junction and to reverse the cardiotoxic effects of hypermagnesemia.
 - Physostigmine at 0.02 mg/kg every 12 hours IV to antagonize the neurotoxic effects of hypermagnesemia.

Precautions/Interactions

- Hypomagnesemia
 - Parenteral administration of magnesium sulfate may result in hypocalcemia due to chelation of calcium with the sulfate. Therefore, magnesium chloride should be administered when hypocalcemia is already present.
 - Side effects of supplemental magnesium therapy include hypotension, atrioventricular and bundle-branch blocks. Adverse effects are usually associated with intravenous boluses rather than continuous rate infusions.
 - Monitor ECG and blood pressure closely if administering magnesium rapidly IV.
 - Decrease supplemental magnesium dose by 50 percent if renal disease or atrioventricular block is present and monitor ECG.
 - Avoid drugs such as aminoglycosides, cisplatin, and cyclosporine because they can cause renal tubular injury and lead to increased renal loss of magnesium.
 - Avoid drugs such as furosemide, thiazides, and mannitol because they can increase renal loss of magnesium.
- Hypermagnesemia
 - Avoid magnesium containing drugs such as cathartics, laxatives, and antacids.
 - Monitor ECG while administering calcium gluconate.
 - Do not administer furosemide to dehydrated, hypotensive, or shocky patients.

Diet

- Many veterinary critical care diets contain low concentrations of magnesium (range 0.1–0.22 mg/kcal). Given that many critically ill patients are fed at or below their resting energy requirement, the actual intake of magnesium may be well below the concentration needed to replete a magnesium deficient animal.
- Magnesium supplementation in standard total parenteral nutrition formulations (0.13–0.22 mEq/kg per day) is also below the concentration recommended to treat hypomagnesemia (0.3–1.0 mEq/kg per day).
- Based on low concentrations of magnesium in critical care diets and total parenteral nutrition formulations, animals with moderate to marked hypomagnesemia will likely require intravenous or oral magnesium supplementation to normalize serum magnesium concentrations, especially if they have disease processes resulting in continued loss of magnesium from the gastrointestinal tract and/or kidneys.

Activity

- Both moderate to marked hypo- and hypermagnesemia can cause weakness, and the patient may require assistance when standing or walking.

Surgical Considerations

- Due to magnesium's effect on the cardiovascular and neuromuscular systems, moderate to marked hypo- or hypermagnesemia should be corrected prior to anesthesia and surgery.



COMMENTS

- 1 mEq of magnesium is equal to 12 mg of magnesium which is equal to 0.5 mmol of magnesium. To convert from mg/dL to mEq/L, divide by 1.2.

Client Education

- Monitor for signs of hypo- or hypermagnesemia. Unfortunately, many of the clinical signs for these electrolyte disorders are nonspecific (e.g., weakness, lethargy, and depression).

Patient Monitoring

- Recheck total serum or ionized magnesium concentrations until normalized. The recheck interval will depend on the severity of the electrolyte disorder, clinical stability of the patient, and the underlying disease process.

Prevention/Avoidance

- Work with veterinarian to resolve or control the underlying disease process that leads to the animal's hypo- or hypermagnesemia.

Possible Complications

- Severe, untreated hypo- and hypermagnesemia can be fatal.

Expected Course and Prognosis

- Depending on the underlying disease process, prognosis can range from guarded to good. The prognosis for correcting and resolving hypermagnesemia secondary to acute anuric renal failure is likely guarded, while the prognosis for correcting and resolving hypomagnesemia secondary to lactation is good.

Abbreviations

- ECG: electrocardiogram
- IM: intramuscularly
- IV: intravenously
- NaCl: sodium chloride
- PO: by mouth
- PTH: parathyroid hormone
- SQ: subcutaneously

See Also

- Disorders of potassium and calcium.

Suggested Reading

- Bateman, S. Disorders of magnesium: Magnesium deficit and excess. In: DiBartola, SP, ed. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed., pp. 210–226. St. Louis: Saunders, 2006.
- Cortés, YE, and Moses, L. Magnesium disturbances in critically ill patients. *Comp Contin Educ Pract Vet* 2007;29:420–427.
- Fascetti, AJ. Magnesium: Pathophysiological, clinical, and therapeutic aspects. In: *Proceedings of the Twenty-first American College of Veterinary Internal Medicine Forum, Charlotte*, June 4–8, 2003.
- Hackett, T. Hypermagnesemia and hypomagnesemia. In: Tilley, LP, and Smith, FWK, eds. *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*, 4th ed., pp. 668–669, 714–715. Ames: Blackwell Publishing, 2008.
- Martin, LG. Magnesium disorders. In: Silverstein, DC and Hopper, K eds. *Small Animal Critical Care Medicine*, pp. 240–243. St. Louis: Saunders, 2008.

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Marijuana Intoxication



DEFINITION/OVERVIEW

- Toxicity from the oral or inhaled exposure to 9-THC, the primary component of marijuana (*Cannabis sativa*) that causes its clinical effects
- Causes primarily neurological depression, ataxia, and urinary incontinence but can also cause gastrointestinal signs (most commonly vomiting)



ETIOLOGY/PATHOPHYSIOLOGY

- Oral exposure is the most commonly reported route, although there are reports of teenagers exposing their pets to marijuana smoke.
- THC acts on a unique cannabinoid receptor in the brain that causes CNS signs.
- The onset of effects occurs within 30 to 90 minutes after ingestion or exposure; signs may last up to 72 hours.
- THC undergoes enterohepatic recirculation and has a long half-life due to lipid solubility.
- THC is excreted in the urine, feces, and bile.
- Oral LD50
 - Dogs 3 g/kg
 - Cats 200 mg/kg
- Fatalities are rare.
- Clinical signs occur at much lower doses.

Systems Affected

- Nervous: THC affects a variety of neurotransmitters, including dopamine, serotonin and GABA, and results in CNS depression.
- Gastrointestinal: Although THC has antiemetic properties, it can cause vomiting in dogs and cats.
- Cardiac: Bradycardia and hypotension may occur secondary to CNS depression, and tachycardia may also occur.



SIGNALMENT/HISTORY

- Dogs account for 96 percent of the exposures; cats account for 3 percent.
- Due to the inquisitive nature of puppies, younger dogs (<1 year) were the predominant patients in one study.

Risk Factors/Causes

- Client households with teenage children may have a higher incident but can occur in all households or with environmental exposure

Historical Findings

- Tactful questioning must be employed when marijuana exposure is suspected.
- Owners may report ataxia, depression, and urinary incontinence.



CLINICAL FEATURES

- Neurologic signs included: depression, ataxia, tremors, seizures, mydriasis, disorientation, behavioral disorders, hyperesthesia, hyperactivity, head bobbing, recumbency, and stupor.
- Other signs reported: hypothermia, bradycardia, vocalization, anorexia, urinary incontinence, and tachycardia



DIFFERENTIAL DIAGNOSIS

- Other potential toxins causing CNS depression must be considered as differential diagnosis including: ethanol, ethylene glycol, ivermectin, opioids, barbiturates, benzodiazepines, phenothiazines, amphetamines, antihistamines, cocaine, methylxanthines, and tricyclic antidepressants.



DIAGNOSTICS

- No specific serum chemistry profile abnormalities
- THC is detectable in urine and plasma, and urine drug screening tests are commercially available. The sensitivity of a urine drug screening test may be affected by amount of THC ingested, time elapsed since ingestion, and water consumption after ingestion.



THERAPEUTICS

- Because there is no specific antidote for marijuana toxicity, therapy is targeted at minimizing absorption and supportive care.
- Decontamination:
 - Induce emesis within 30 minutes of ingestion and if patient is asymptomatic.
 - Induction of emesis may be difficult due to the potent antiemetic properties of THC.
 - Orogastric lavage under general anesthesia with cuffed endotracheal tube in place
 - Administer activated charcoal every 8 hours for the first 24 hours due to entero-hepatic recirculation; use cautiously or not at all in recumbent animals because of risk of aspiration.
- For symptomatic animals: intravenous fluids (balanced electrolyte solution), thermoregulation, alternating body position every 4 hours

Drug(s) of Choice

- Diazepam (0.25–0.5 mg/kg IV) for agitation or seizures; start with lower dose to prevent excessive sedation
- Atropine sulfate (0.02–0.04 mg/kg IV, IM, or SQ) for severe bradycardia

Precautions/Interactions

- Other CNS depressing drugs should be minimized due to the cumulative effect.

Activity

- Provide a quiet, darkened environment with minimal stimulation.



COMMENTS

Patient Monitoring

- Monitor respiratory function (aspiration pneumonia or atelectasis can occur with prolonged recumbency), cardiac function (heart rate, blood pressure), and body temperature every 2 to 4 hours.

Possible Complications

- THC can lower the seizure threshold in humans, it is unclear if this occurs in dogs and cats.

Expected Course and Prognosis

- The prognosis is favorable for symptomatic animals with no secondary complications such as aspiration pneumonia. With supportive care, affected animals usually recover within 72 hours.

Synonyms

- Hemp, Mary Jane, grass, pot, weed, hashish, THC, ganja, wacky weed

Abbreviations

- CNS: central nervous system
- GABA: gamma-aminobutyric acid
- LD50: lethal dose that kills 50 percent of animals tested
- IM: intramuscularly
- IV: intravenously
- SQ: subcutaneously
- THC: tetrahydrocannabinol

Suggested Reading

Donaldson, CW. Marijuana exposure in animals. *Vet Med* 2002;97:437–439.

Donaldson, CW, and Gwaltney, S. Two hundred and thirteen cases of marijuana toxicoses in dogs. *Vet Human Toxicol* 2004;46:19–21.

Macintire, DK, Drobatz, KJ, Haskins, SC, and Saxon, WD. *Manual of Small Animal Emergency and Critical Care Medicine*, p. 396.. Philadelphia: Lippincott Williams and Wilkins, 2005.

Mathews, KA. *Emergency Critical Care*, 2nd ed., pp. 653–654. Guelph: Lifelearn, 2006.

Author: Elizabeth Ashbaugh

Metabolic Acidosis



DEFINITION/OVERVIEW

- Decrease in plasma pH associated with a decrease in HCO_3^- concentration (dogs, $<18 \text{ mEq/L}$; cats, $<16 \text{ mEq/L}$) and a compensatory decrease in PCO_2



ETIOLOGY/PATHOPHYSIOLOGY

- Metabolic acidosis may develop secondary to hyperphosphatemia (hyperphosphatemic acidosis), corrected hyperchloremia (hyperchloremic acidosis), and accumulation of metabolically produced strong anions (strong ion gap or high-AG acidosis). The most common causes of metabolic acidosis in critical care patients are presented in Table 62.1.
- Metabolic acidoses, especially lactic acidosis, uremic acidosis, and diabetic ketoacidosis, occur commonly in critically ill patients.
- Hyperphosphatemic acidosis
 - Increase in plasma weak acids (e.g., inorganic phosphate) is associated with metabolic acidosis and increased AG. At pH of 7.4, a 1 mg/dL increase in phosphate concentration is associated with a 0.58 mEq/L decrease in HCO_3^- and a 0.58 mEq/L increase in AG.
- Hyperchloremic acidosis
 - Hyperchloremic acidosis may be caused by chloride retention (e.g., renal failure, renal tubular acidosis), excessive loss of sodium relative to chloride (e.g., diarrhea), or by administration of substances containing more chloride than sodium as compared with normal extracellular fluid composition (e.g., administration of KCl, 0.9% NaCl).
 - In critically ill patients the source of hyperchloremic acidosis is often iatrogenic. A common cause is related to the volume of saline infused during resuscitation from shock.
 - Acidemia is usually not severe in patients with hyperchloremic acidosis.
- High-AG acidosis
 - Increase in the concentration of other strong anions: addition (e.g., ethylene glycol toxicity), excessive production (e.g., lactate produced by prolonged anaerobic metabolism), or renal retention (e.g., renal failure) of strong anions other than

TABLE 62.1 Common Causes of Metabolic Acidosis in Patients Who Are Critically Ill*

Pre-Existing Disease Process

Hyperphosphatemic acidosis

Renal failure

Urethral obstruction

Hyperchloremic acidosis

Renal tubular acidosis

Renal failure

Diarrhea

High AG acidosis

Diabetes mellitus

Renal failure

Labile Feature of an Evolving Process

Hyperphosphatemic Acidosis

Phosphate-containing enemas

Acute renal failure

Hyperchloremic acidosis

Diarrhea

Post correction of chronic respiratory alkalosis

High AG acidosis

Diabetic ketoacidosis

Uremic acidosis

Lactic acidosis

Toxicities (e.g., ethylene glycol, salicylates)

Iatrogenic

Hyperphosphatemic acidosis

IV phosphate administration

Hyperchloremic acidosis

0.9% NaCl administration

KCl administration

Total parenteral nutrition

High AG acidosis

Propylene glycol intravenously as drug vehicle (e.g., nitroglycerin, diazepam)

Gelatin administration (increases anion gap without causing acidosis)

AG, anion gap; IV, intravenous; KCl, potassium chloride; NaCl, sodium chloride

*Adapted from: de Morais HA, Bach JF, DiBartola SP. Metabolic acid-base disorders in the critical care unit. *Vet Clin N Am Small Anim Pract* 2008;38:563, with permission.

chloride causes metabolic acidosis without increasing chloride concentration (so-called normochloremic or high AG metabolic acidosis).

- A mnemonic to remember causes of high-AG metabolic acidosis is A MUD PILE, where:

A: Aspirin (salicylates)

M: Metaldehyde

U: Uremia

D: Diabetic ketoacidosis

- P: Paraldehyde
- I: Iron
- L: Lactic acidosis
- E: Ethanol and ethylene glycol

Systems Affected

- Respiratory—Increased H^+ stimulates peripheral and central chemoreceptors to increase alveolar ventilation; hyperventilation decreases PCO_2 , which counters the effects of low plasma HCO_3^- on pH. In dogs, a decrease of approximately 0.7 mm Hg in PCO_2 is expected for each 1 mEq/L decrease in plasma HCO_3^- . Little is known about compensation in cats, but it appears to be almost non-existent.
- Renal/Urologic—the kidneys increase net acid excretion, primarily by increasing excretion of NH_4^+ and chloride. This compensatory mechanism is not very effective in cats.
- Cardiovascular—A fall in pH results in an increase in sympathetic discharge but simultaneously causes a decrease in the responsiveness of the cardiac myocytes and vascular smooth muscle to the effects of catecholamines. In mildly acidemic conditions (pH greater than 7.2), the effects of increased sympathetic stimulation predominate and result in a mild increase in heart rate and cardiac output. More severe acidemia (pH below 7.1), especially if acute, may decrease cardiac contractility and predispose the heart to ventricular dysrhythmias and ventricular fibrillation.
- Endocrine/Metabolic—Acidemia produces insulin resistance that impairs peripheral uptake of glucose and inhibits anaerobic glycolysis by inhibiting phosphofructokinase.



SIGNALMENT/HISTORY

- Any breed, age, or sex of dogs and cats

Risk Factors/Causes

- Pre-existing diseases with a high risk for metabolic acidosis
 - Chronic renal failure
 - Diabetes mellitus
 - Hypoadrenocorticism
- Patients with poor tissue perfusion or hypoxia are at risk of developing lactic acidosis.

Historical Findings

- History associated with chronic disease processes that may lead to metabolic acidosis (e.g., renal failure, diabetes mellitus, hypoadrenocorticism, or diarrhea)
- Exposure to toxins (e.g., ethylene glycol, salicylate, and paraldehyde)



CLINICAL FEATURES

- Generally related to the underlying disease
- Depression in severely acidotic patients
- Tachypnea in some patients results from compensatory increase in ventilation.
- Kussmaul's respiration, typically seen in human beings with metabolic acidosis, is not commonly observed in dogs and cats.



DIFFERENTIAL DIAGNOSIS

- Low plasma HCO_3^- and hyperchloremia may also be compensatory in animals with chronic respiratory alkalosis, in which PCO_2 is low and pH is high or near normal, despite decreased HCO_3^- and increase in chloride concentration. Blood gas determination is required to differentiate.



DIAGNOSTICS

- Blood gas analysis reveals low HCO_3^- , low PCO_2 , and low pH.
 - Excessive heparin (>10 percent of the sample) decreases HCO_3^- and the degree of the acidosis may be overestimated.
- AG
 - Metabolic acidoses are traditionally divided into hyperchloremic and high AG by means of the AG. AG, the difference between the measured cations and the measured anions, is calculated as $\text{AG} = \text{Na}^+ - (\text{HCO}_3^- + \text{Cl}^-)$ or $\text{AG} = (\text{Na}^+ + \text{K}^+) - (\text{HCO}_3^- + \text{Cl}^-)$, depending on the preference of the clinician or laboratory. Normal values with potassium included in the calculation are usually 12 to 24 mEq/L in dogs and 13 to 27 mEq/L in cats. The negative charges of albumin are the major contributors to the normal AG; this should be taken into account when evaluating AG in patients with hypoalbuminemia. At pH 7.4 in dogs, a decrease of 1 g/dL in albumin is associated with a decrease of 4.1 mEq/L in the AG.
 - Normal AG: hyperchloremic metabolic acidosis
 - High AG: hyperphosphatemic acidosis, uremic acidosis, ketoacidosis, lactic acidosis, toxicities (e.g., ethylene glycol).
- Hyperglycemia—consider diabetes mellitus.
- Azotemia—consider renal failure.
- Hyperphosphatemia—consider renal failure, hypertonic sodium phosphate enema toxicity, and toxicity due to urinary acidifiers containing phosphate.
- High lactate concentration—consider lactic acidosis associated with poor tissue perfusion or poor metabolism of lactate (e.g., liver disease and lymphoma).

- Hyperkalemia—commonly associated with, but almost never caused by the acidosis. Hyperkalemia results from the disease process causing the metabolic acidosis (e.g., poor renal function in renal failure or lack of insulin in diabetes mellitus), not from the acidosis itself. Correction formulas to adjust potassium concentration based on pH changes should not be used.



THERAPEUTICS

- Acid-base disturbances are secondary phenomena; successful resolution depends on diagnosis and treatment of the underlying disease process.
- Treat patients with blood pH < 7.1 aggressively while pursuing the definitive diagnosis.
- Discontinue drugs that may cause or contribute to metabolic acidosis.

Drug(s) of Choice

- NaHCO_3 may help patients with hyperchloremic, hyperphosphatemic or uremic acidosis but not patients with lactic acidosis or diabetic ketoacidosis.
 - Estimation of HCO_3^- dose: dogs, $0.3 \times \text{body weight (kg)} \times (21 - \text{patient } \text{HCO}_3^-)$; cats, $0.3 \times \text{body weight (kg)} \times (19 - \text{patient } \text{HCO}_3^-)$. Give half of this dose slowly IV and reevaluate blood gases before deciding on the need for additional administration. An empirical dose of 2 mEq/kg followed by reevaluation of blood gas status is safe in most patients.
 - Potential complications of NaHCO_3 administration: volume overload resulting from administered sodium, tetany from low ionized calcium concentration, increased affinity of hemoglobin for oxygen, paradoxical CNS acidosis, overshoot metabolic alkalosis, and hypokalemia.
- Hyperchloremic acidosis: NaHCO_3 is effective and should be considered whenever pH < 7.2.
- Uremic acidosis: Efficacy of NaHCO_3 in acute therapy of uremic acidosis is related to the shift of phosphate inside the cells and consequent amelioration of hyperphosphatemic acidosis.
- Lactic acidosis: NaHCO_3 increases lactate production and is of little to no value in lactic acidosis. Therapy should be directed at augmenting oxygen delivery to the tissues and reestablishing cardiac output. Small titrated doses of NaHCO_3 can be used as a temporizing measure to maintain HCO_3^- above 5 mEq/L, if needed.
- Diabetic ketoacidosis: NaHCO_3 adversely affects outcome in humans with diabetic ketoacidosis even when pH is below 7.0. Administration of NaHCO_3 to ketoacidotic patients cannot be recommended at any pH. Therapy should be directed at insulin and fluid administration. Reestablishing plasma volume and renal perfusion will allow the kidneys to excrete ketoanions, replacing them with chloride.

Precautions/Interactions

- Avoid NaHCO_3 in patients with respiratory acidosis because it generates CO_2 . Patients with respiratory acidosis cannot adequately excrete CO_2 , and increased PCO_2 will further decrease the pH.
- Avoid diuretics that act in the distal nephron (e.g., spironolactone).
- Avoid carbonic anhydrase inhibitors (e.g., acetazolamide).
- Use NaHCO_3 cautiously in patients with congestive heart failure because the sodium load may cause decompensation of the heart failure.

Activity

- Restriction dictated by the underlying disease leading to metabolic acidosis



COMMENTS

Patient Monitoring

- Acid-base status—frequency dictated by the underlying disease and patient response to treatment

Possible Complications

- Myocardial depression and ventricular arrhythmias

Expected Course and Prognosis

- Prognosis is dependent on the severity of the underlying disease causing metabolic alkalosis and response to therapy.

Synonyms

- Nonrespiratory acidosis
- Hyperchloremic acidosis—normal AG acidosis
- Normochloremic acidosis—high AG acidosis
- Hyperphosphatemic acidosis—metabolic acidosis resulting from high phosphate concentration
- Organic acidosis—metabolic acidosis resulting from accumulation of organic anions (e.g., ketoacidosis, uremic acidosis, and lactic acidosis)
- Dilutional acidosis—metabolic acidosis resulting from increased free water in plasma

Abbreviations

- AG: anion gap
- Cl: chloride
- CNS: central nervous system

- CO_2 : carbon dioxide
- H^+ : hydrogen ion
- HCO_3^- : bicarbonate
- IV: intravenously
- K: potassium
- KCl: potassium chloride
- Na: sodium
- NaCl: sodium chloride
- NaHCO_3 : sodium bicarbonate
- NH_4 : ammonium
- O_2 : oxygen
- PCO_2 : carbon dioxide tension
- pH: acid-base balance

Suggested Reading

- de Moraes, HA, Bach, JF, and DiBartola, SP. Metabolic acid-base disorders in the critical care unit. *Vet Clin N Am Small Anim Pract* 2008;38:559–574
- de Moraes, HA, and Constable, PD. Strong ion approach to acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 310–321. Philadelphia: Saunders, 2006.
- de Moraes, HA, and Leisewitz, AL. Mixed acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 296–309. Philadelphia: Saunders, 2006.
- DiBartola, SP. Metabolic acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 251–283. Philadelphia: Saunders, 2006.

Author: Helio Autran de Moraes

Metabolic Alkalosis



DEFINITION/OVERVIEW

- Increase in pH associated with an increase in plasma HCO_3^- concentration (dogs $> 24 \text{ mEq/L}$; cats $> 22 \text{ mEq/L}$) and a compensatory increase in PCO_2 .



ETIOLOGY/PATHOPHYSIOLOGY

- Metabolic alkalosis may develop secondary to corrected hypochloremia (hypochloremic alkalosis) or hypoalbuminemia (hypoalbuminemic alkalosis). The most common causes of metabolic alkalosis in critical care patients are presented in Table 63.1.
- Hypochloremic alkalosis
 - Fluid rich in chloride and H^+ may be lost via the alimentary tract (e.g., vomiting, stomach drainage) or kidneys (e.g., diuretic therapy). Loss of chloride and H^+ is associated with an increase in plasma HCO_3^- concentration. With chloride loss and volume depletion, the kidneys reabsorb sodium with HCO_3^- instead of chloride, perpetuating the metabolic alkalosis.
 - Administration of fluids with high sodium and poor chloride concentration (e.g., sodium bicarbonate) also may result in transient metabolic alkalosis.
 - Hypochloremic alkalosis is not common in dogs and cats in a critical care setting and is usually secondary to vomiting or diuretic administration. Alkalemia is rare unless the patient also has respiratory alkalosis.
- Hypoalbuminemic alkalosis
 - Decrease in plasma weak acids (e.g., albumin) is associated with metabolic alkalosis.
 - Hypoalbuminemic alkalosis is common in critically ill patients, but it rarely leads to alkalemia. However, presence of hypoalbuminemia complicates identification of increased unmeasured anions (e.g., lactate, ketoanions) because hypoalbuminemia decreases AG. At plasma pH of 7.4 in dogs, each decrease of 1 g/dL in albumin concentration is associated with a decrease of 4.1 mEq/L in the AG. Thus, the severity of the underlying disease leading to metabolic acidosis may be underestimated if the effects of hypoalbuminemia on pH, HCO_3^- concentration, and AG are not considered.

TABLE 63.1 Common Causes of Metabolic Alkalosis in Patients Who Are Critically Ill*

Pre-existing Disease Process

- Hypoalbuminemic alkalosis
 - Liver failure
 - Protein-losing enteropathy
 - Protein-losing nephropathy
- Hypochloremic alkalosis
 - Diuretic therapy
 - Vomiting of stomach contents

Labile Feature of an Evolving Process

- Hypoalbuminemic alkalosis
 - Vasculitis
 - Third space losses
- Hypochloremic alkalosis
 - Vomiting of stomach contents
 - Post correction of chronic respiratory acidosis

Iatrogenic

- Hypochloremic alkalosis
 - Bicarbonate administration
 - Diuretic therapy
 - Stomach draining

*From: de Moraes HA, Bach JF, DiBartola SP. Metabolic acid-base disorders in the critical care unit. *Vet Clin N Am Small Anim Pract* 2008;38:561, with permission.

Systems Affected

- **Respiratory:** Low H^+ reduces alveolar ventilation. Hypoventilation increases PCO_2 and helps offset the effects of high plasma HCO_3^- on pH. In dogs, an increase of approximately 0.7 mmHg in PCO_2 can be expected for each 1 mEq/L increase in plasma HCO_3^- . Limited data is available for cats, but the degree of respiratory compensation appears to be similar.
- **Renal/Urologic:** The kidneys rapidly and effectively excrete excessive alkali. In patients with chloride deficiency (and less importantly, volume depletion), the kidneys cannot excrete the excessive alkali and metabolic alkalosis is maintained. In these patients, chloride administration is required for renal compensation to occur, whereas volume expansion will hasten compensation.
- **Nervous:** Muscle twitching and seizures occur rarely in dogs. Metabolic alkalosis and associated hypokalemia may precipitate hepatic encephalopathy in patients with liver failure.



SIGNALMENT/HISTORY

- Any breed, age, or sex of dogs and cats

Risk Factors/Causes

- Administration of loop or thiazide diuretics
- Vomiting
- Stomach drainage
- Vasculitis (hypoalbuminemia)

Historical Findings

- Administration of loop diuretics (e.g., furosemide) or thiazides
- Vomiting



CLINICAL FEATURES

- Signs related to the underlying disease or accompanying potassium depletion (e.g., weakness, cardiac arrhythmias, and ileus)
- Muscle twitching caused by low ionized calcium concentration
- Dehydration in volume-depleted patients
- Muscle twitching and seizures in patients with neurologic involvement (rare)



DIFFERENTIAL DIAGNOSIS

- High plasma HCO_3^- and hypochloremia in animals can also be compensating for chronic respiratory acidosis, in which PCO_2 is high and pH is low despite high HCO_3^- and low chloride concentration; blood gas determination required to differentiate.



DIAGNOSTICS

- Metabolic alkalosis: Blood gas analysis reveals high HCO_3^- , high PCO_2 , and high pH.
 - Excessive heparin (>10 percent of the sample) decreases HCO_3^- and the degree of the alkalosis may be underestimated.
- Hypochloremic alkalosis: associated with a decrease in corrected chloride concentration
- Hypoalbuminemic alkalosis: associated with a decrease in albumin concentration. In vitro, a 1 g/dL decrease in albumin concentration is associated with an increase in pH of 0.093 in cats and 0.047 in dogs.
- Hypokalemia: Hypokalemia is common in patients with metabolic alkalosis. It likely results from the metabolic alkalosis or the underlying problem (e.g., vomiting of stomach contents or loop diuretic administration); hypokalemia-induced metabolic alkalosis does not occur in dogs and cats.



THERAPEUTICS

- Acid-base disturbances are secondary phenomena. Diagnosis and treatment of the underlying disease process are integral to the successful resolution of acid-base disorders.
- Severe alkalemia is uncommon but may be life threatening. Patients with chronic respiratory disease and respiratory alkalosis are at risk of developing severe alkalemia if they start vomiting or receive diuretics.
- Discontinue drugs that may cause metabolic alkalosis.

Drug(s) of Choice

- Hypochloremic alkalosis:
 - If there is evidence of volume depletion, the deficit should be repaired with a chloride-containing fluid (e.g., 0.9% NaCl).
 - If the metabolic alkalosis is associated with hypokalemia and total body potassium deficits, correcting the deficit with KCl is a particularly effective way to reverse the alkalosis.
- Hypoalbuminemic alkalosis:
 - Treatment for hypoalbuminemic alkalosis should be directed at the underlying cause and the decreased colloid oncotic pressure.

Precautions/Interactions

- In the absence of hypovolemia, the amount of saline required to correct hypochloremic alkalosis introduces a risk for volume overload.
- Avoid chloride-free fluids; they may correct volume depletion but will not correct metabolic alkalosis.
- Avoid using salts of potassium without chloride (e.g., potassium phosphate); potassium will be excreted in the urine and will correct neither the alkalosis nor the potassium deficit.

Alternative Drugs

- Acetazolamide (5–10 mg/kg every 8 hours PO) can be used to as adjunct therapy for the correction of metabolic alkalosis in critical care patients.

Activity

- Restriction dictated by the underlying disease leading to metabolic alkalosis



COMMENTS

Patient Monitoring

- Acid-base status: frequency dictated by the underlying disease and patient response to treatment

Expected Course and Prognosis

- Prognosis is dependent on the severity of the underlying disease causing metabolic alkalosis and response to therapy.

Synonyms

- Nonrespiratory alkalosis
- Hypochloremic alkalosis: metabolic alkalosis caused by low chloride concentration
- Hypoalbuminemic alkalosis: metabolic alkalosis caused by low albumin concentration
- Concentration alkalosis: metabolic alkalosis resulting from decreased free water in plasma
- Contraction alkalosis: metabolic alkalosis formerly attributed to volume contraction but now known to be caused by chloride depletion. Volume depletion is a common but not essential feature.

Abbreviations

- AG: anion gap
- H⁺: hydrogen ion
- HCO₃⁻: bicarbonate
- KCl: potassium chloride
- NaCl: sodium chloride
- PCO₂: carbon dioxide tension
- pH: acid-base balance
- PO: by mouth

Suggested Reading

- de Moraes, HA, Bach, JF, and DiBartola, SP. Metabolic acid-base disorders in the critical care unit. *Vet Clin N Am Small Anim Pract* 2008;38:559–574.
- de Moraes, HA, and Constable, PD. Strong ion approach to acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 310–321. Philadelphia: Saunders, 2006.
- de Moraes, HA, and Leisewitz, AL. Mixed acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 296–309. Philadelphia: Saunders, 2006.
- DiBartola, SP. Metabolic acid-base disorders. In: DiBartola, SP, ed. *Fluid, Electrolyte and Acid-Base Disorders*, 3rd ed., pp. 251–283. Philadelphia: Saunders, 2006.

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Metaldehyde Toxicosis



DEFINITION/OVERVIEW

- Syndrome of toxicity that occurs in dogs and cats after ingestion of metaldehyde, a common chemical in commercial slug baits.



ETIOLOGY/PATHOPHYSIOLOGY

- Metaldehyde is a tetramer of acetaldehyde and is a common component of commercial slug baits.
- Mechanism of toxicity unknown in small animals.
- LD50 is 100 mg/kg in dogs, and 207 mg/kg in cats. Clinical signs can occur after ingestion of 2 mg/kg. Clinical signs of toxicity can occur within minutes to several hours after ingestion.
- Proposed mechanism of toxicity involves the conversion of metaldehyde to acetaldehyde in the stomach when exposed to an acidic environment, with possible decreased concentrations of the inhibitory neurotransmitter GABA, decreased norepinephrine, and decreased 5-HT. The decreased concentration of inhibitory neurotransmitters has been linked with increased incidence of seizure activity and death.

Systems Affected

- Neurologic—nystagmus, muscle rigidity, tremors, opisthotonus, hyperesthesia, and seizures. Transient blindness has been reported.
- Musculoskeletal—muscle rigidity and tremors or fasciculations
- Gastrointestinal—vomiting and diarrhea
- Metabolic—respiratory alkalosis from panting, metabolic acidosis, or hyperthermia
- Respiratory—panting, respiratory depression and failure within hours of ingestion/exposure
- Hepatobiliary—hepatic failure delayed up to 2 to 3 days after exposure

Incidence/Prevalence

- Unknown

Geographic Distribution

- Can occur anywhere, but more common in geographic locations that have problems with slug infestations in gardens (i.e., Southern United States, Hawaiian Islands, and Pacific coast)



SIGNALMENT/HISTORY

Species

- Dogs and cats

Historical Findings

- History of exposure or ingestion
- Acute onset of tremors, hyperexcitability, nystagmus, vomiting, diarrhea, or seizures

Physical Examination Findings

- Tachycardia
- Blindness
- Tachypnea
- Nystagmus
- Tremors
- Hyperesthesia
- Ataxia
- Seizures

Risk Factors/Causes

- Exposure to metaldehyde
- Free-roaming activity in a geographic location where slugs and gardeners coexist



DIFFERENTIAL DIAGNOSIS

- Differential diagnoses include intoxication with bromethalin, 1080 compound, strychnine, chlorinated hydrocarbons, organophosphates, zinc phosphide, methylxanthines, tremorigenic mycotoxins, lead, and illicit recreational drugs such as cocaine, amphetamine and methamphetamine.

Complete Blood Count/Biochemistry/Urinalysis

- CBC—Stress leukogram, thrombocytopenia in severe cases that are hyperthermic
- Biochemistry—Elevated ALT and CPK from muscle tremors, hyperglycemia, or hyperbilirubinemia
- Urinalysis—Myoglobinuria from severe muscle tremors

Other Laboratory Tests

- Gas chromatography is an ion trap mass spectroscopy to determine presence of metaldehyde or its metabolite acetaldehyde in urine, gastric contents, and plasma.

Diagnostic Procedures

- CBC, chemistry, urinalysis, tremorigen assay (Michigan State University Veterinary Diagnostic Laboratory)



THERAPEUTICS

- Decrease further absorption/induction of emesis
- Treat tremors
- Anticonvulsant drugs
- Correct acid-base disturbances
- Correct hyperthermia
- Correct dehydration
- Antiemetics

Drug(s) of Choice

Apomorphine

- Induce emesis
- 0.03 to 0.04 mg/kg IV

Methocarbamol

- Muscle relaxant
- 55 to 220 mg/kg IV slowly to effect, no more than 330 mg/kg per 24 hours

Diazepam

- Muscle relaxant, control of seizures
- 0.5 to 1 mg/kg IV or per rectum

Phenobarbital

- Anticonvulsant
- 16 to 20 mg/kg IV may be administered as a bolus if animals are in status epilepticus, or divided into 4 mg/kg doses and administered every 30 to 60 minutes until total dose has been administered. Use caution because phenobarbital and acetaldehyde are metabolized by the cytochrome P450 enzyme system, and administration of phenobarbital can potentially decrease the metabolic degradation and excretion of acetaldehyde.

Activated Charcoal

- Prevent further absorption, repeat every 6 to 8 hours as long as patient is able to swallow and has an intact gag reflex.
- Administer dose according to manufacturer's recommendations.
- Sorbitol-containing activated charcoal solutions or concentrate may promote elimination from gastrointestinal tract but should be avoided in animals with diarrhea and vomiting.

Intravenous Crystalloid Fluids

- Dose is dependent on degree of hyperthermia, dehydration, and acid-base and electrolyte abnormalities. Make sure to correct fluid deficits, acid-base and electrolyte abnormalities, and provide maintenance needs.

Anti-Emetics

- Dolasetron (0.6 mg/kg IV every 24 hours)
- Ondansetron (1 mg/kg IV every 8–12 hours)
- Cerenia (1 mg/kg SQ; 2 mg/kg PO)
- Metoclopramide (1–2 mg/kg per day IV CRI)

Contraindications

- Do not submerge in ice water baths.
- Caution with sorbitol in animals with vomiting or diarrhea and are dehydrated.

**COMMENTS****Patient Monitoring**

- Check liver enzyme activities several days after exposure because delayed hepatic failure can occur.

Prevention/Avoidance

- Prevent free roaming in geographic locations where slugs and gardeners coexist.

Possible Complications

- DIC
- Rhabdomyolysis
- Renal failure
- Neurologic sequelae
- Hepatic failure
- Death

Expected Course and Prognosis

- Half-life of metaldehyde is unknown in dogs. Prognosis is generally good if exposure is witnessed and emesis is induced before onset of clinical signs. Prognosis is worse if severe hyperthermia, DIC, rhabdomyolysis, and organ failure occur. Survival of 83 percent was reported in one study.

Abbreviations

- ALT: alanine transaminase
- CBC: complete blood count
- CPK: creatine phosphokinase
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- GABA: gamma-amino-butyric acid
- IV: intravenously
- LD50: lethal dose that kills 50 percent of animals tested
- PO: by mouth
- SQ: subcutaneously
- 5HT: 5-hydroxytryptamine (serotonin)

Suggested Reading

Dolder, LK. Metaldehyde toxicosis. *Vet Med* 2003;98(3):213–215.

Richardson, JA, Welch, SL, Gwaltney-Brandt, SM, Huffman, JD, and Rosendale, ME. Metaldehyde toxicosis in dogs. *Comp Educ Pract Vet* 2003;25(5):376–379.

Yas-Natan, E, Segey, G, and Aroch, I. Clinical, neurological, and clinicopathological signs, treatment and outcome of metaldehyde intoxication in 18 dogs. *J Sm Anim Pract* 2007;48(8):438–443.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Konstanze E. Plumlee

Murmurs



DEFINITION/OVERVIEW

- Vibrations caused by disturbed blood flow

Timing of Murmurs

- Systolic murmurs occur between S1 and S2 (systole).
- Diastolic murmurs occur between S2 and S1 (diastole).
- Continuous and to-and-fro murmurs occur throughout all or most of the cardiac cycle.
- Continuous murmurs are usually accentuated near S2 and to-and-fro murmurs are usually absent near S2.

Grading Scale for Murmurs

- Grade I—barely audible
- Grade II—soft, but easily auscultated. Does not radiate far from PMI
- Grade III—intermediate loudness; heard easily some distance from PMI, but not to opposite side of chest; most hemodynamically important murmurs are at least grade III.
- Grade IV—loud murmur radiating widely, often including opposite side of chest
- Grade V—very loud, audible with stethoscope barely touching the chest; palpable thrill
- Grade VI—very loud, audible without the stethoscope touching the chest; palpable thrill

Configuration

- Plateau murmurs have uniform loudness and are typical of regurgitant murmurs such as mitral and tricuspid insufficiency and ventricular septal defect.
- Crescendo-decrescendo murmurs get louder and then softer and are typical of ejection murmurs such as pulmonic and aortic stenosis and atrial septal defect.
- Decrescendo murmurs start loud and then get softer and are typical of diastolic murmurs such as aortic or pulmonic insufficiency and mitral or tricuspid stenosis.

Location

Dogs

- Mitral area—left fifth intercostal space at costochondral junction
- Aortic area—left fourth intercostal space above costochondral junction
- Pulmonic area—left second to fourth intercostal space at sternal border
- Tricuspid area—right third to fifth intercostal space near costochondral junction

Cats

- Mitral area—left fifth to sixth intercostal space one-fourth ventrodorsal distance from sternum
- Aortic area—left second to third intercostal space just above the pulmonic area
- Pulmonic area—left second to third intercostal space one-third to one-half ventrodorsal distance from sternum
- Tricuspid area—right fourth to fifth intercostal space one-fourth ventrodorsal distance from sternum



ETIOLOGY/PATHOPHYSIOLOGY

- Disturbed blood flow associated with high flow through normal or abnormal valves or with structures vibrating in the blood flow
- Flow disturbances associated with outflow obstruction or forward flow through stenosed valves or into a dilated great vessel
- Flow disturbances associated with regurgitant flow through an incompetent valve, septal defect, or patent ductus arteriosus

Systems Affected

- Cardiovascular



SIGNALMENT/HISTORY

Species

- Dogs and cats

Historical Findings

- Relate to cause of the murmur
- Owner may report having felt a cardiac thrill.

Risk Factors/Causes

- Cardiac disease



CLINICAL FEATURES

- Physical findings vary with the cause of the murmur.
- Murmurs may be systolic, diastolic, or continuous.
- Murmurs vary in loudness, radiation, and PMI depending on the cause and severity.
- Evaluation of jugular and femoral pulses may be helpful in narrowing the differential diagnosis (e.g., jugular pulse with tricuspid insufficiency, bounding pulse with patent ductus arteriosus).



DIFFERENTIAL DIAGNOSIS

Differential Signs

- Must differentiate from other abnormal heart sounds—split sounds, ejection sounds, gallop rhythms, and clicks
- Must differentiate from abnormal lung sounds and pleural rubs; listen to see if timing of abnormal sound is correlated with respiration or heartbeat.

Differential Causes

- Pale mucous membranes support diagnosis of anemic murmur.
- Location and radiation of murmur and timing during cardiac cycle can help determine cause.

Systolic Murmurs

- Mitral and tricuspid valve endocarditis
- Cardiomyopathy and AV valve insufficiency
- Physiologic flow murmurs
- Anemia
- Mitral and tricuspid valve dysplasia
- Systolic anterior mitral motion
- Dynamic right ventricular outflow obstruction
- Dynamic subaortic stenosis
- Atrial septal defect
- Ventricular septal defect
- Pulmonic stenosis
- Aortic stenosis
- Tetralogy of Fallot
- Mitral and tricuspid valve endocarditis

- Hyperthyroidism
- Heartworm disease

Continuous or To-and-Fro Murmurs

- Patent ductus arteriosus
- Ventricular septal defect with aortic regurgitation
- Aortic stenosis with aortic regurgitation

Diastolic Murmurs

- Mitral and tricuspid valve stenosis
- Aortic and pulmonic valve endocarditis

Age-Related Factors

- Murmurs present since birth generally associated with a congenital defect or physiologic flow murmur
- Acquired murmurs in geriatric, small-breed dogs usually associated with degenerative valve disease
- Acquired murmurs in large-breed dogs usually associated with dilated cardiomyopathy
- Acquired murmurs in geriatric cats usually associated with cardiomyopathy or hyperthyroidism



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Anemia in animals with anemic murmurs
- Polycythemia in animals with right-to-left shunting congenital defects
- Leukocytosis with left shift in animals with endocarditis

Imaging

- Thoracic radiography is useful for evaluating heart size and pulmonary vasculature in hopes of determining cause and significance of murmur
- Echocardiography is recommended when a cardiac cause is suspected and the nature of the defect is unknown
- Doppler studies sometimes required to confirm cause of murmur

Diagnostic Procedures

- Electrocardiography may be useful in assessing heart enlargement patterns in animals with murmurs.
- Blood cultures and serology for *Bartonella* if suspect endocarditis

Pathologic Features

- Vary with underlying cause of the murmur



THERAPEUTICS

Drug(s) of Choice

- None unless heart failure has developed secondary to the disease process causing the murmur or if the murmur is secondary to endocarditis

Diet

- Sodium restriction if in congestive heart failure

Surgical Considerations

- Surgery or interventional cardiology procedures may be options in cases of patent ductus arteriosus, pulmonic stenosis, aortic stenosis, or congenital mitral valve disease. Consultation with a veterinary cardiologist is recommended prior to surgical intervention.



COMMENTS

Client Education

- Murmurs are associated with many conditions, some benign and others serious. Echocardiography may be required if the cause of the murmur is not obvious from the history and physical examination.

Patient Monitoring

- Low-grade systolic ejection murmurs in puppies may be physiologic; most resolve by 6 months of age. If murmur is still present after 6 months, include diagnostic imaging.

Possible Complications

- If murmur is associated with structural heart disease, may see signs of congestive heart failure (e.g., coughing, dyspnea, and ascites) or exercise intolerance.

Expected Course and Prognosis

- Varies with underlying cause

Abbreviations

- AV: atrioventricular
- PMI: point of maximal intensity
- S1: first heart sound
- S2: second heart sound

Suggested Reading

Smith, FWK, Jr, Keene, BW, and Tilley, LP. *Rapid Interpretation of Heart and Lung Sounds*. St Louis: Saunders Elsevier, 2006.

Author: Francis W. K. Smith, Jr.

Mycotoxins—Aflatoxins



DEFINITION/OVERVIEW

- Aflatoxins are metabolites produced by fungi (*Aspergillus* and *Penicillium* spp.) that may cause acute hepatic failure.
- Uncommonly diagnosed in dogs, however, outbreaks involving more than 100 cases have been reported.



ETIOLOGY/PATHOPHYSIOLOGY

- Fungal invasion and toxin production in crops during the growing season, during harvest, or during transportation and storage result in accumulation of aflatoxin.
- Despite random screening for aflatoxins by most pet food manufacturers, small amounts often reach the final product undetected.
- Aflatoxins are absorbed via the GI tract and subsequently sequestered in the liver.
- Most dogs require several days to weeks of exposure prior to developing clinical signs of toxicity, although sudden acute intoxication is reported.
- Evidence suggests aflatoxins bind and interfere with DNA, RNA, and protein function leading to carcinogenic, teratogenic, mutagenic and acute hepatotoxic effects.
- Aflatoxin B1 is most frequently reported to cause toxicity.

Systems Affected

- Hepatobiliary—Aflatoxins accumulate in the liver.
- GI—GI ulcers and hemorrhage occur frequently via an unknown mechanism of action.
- Hemic—Aflatoxins are reported to have a Coumadin-like effect that may contribute to the frequent occurrence of hypocoagulable states.



SIGNALMENT/HISTORY

- Young and pregnant animals appear to be more susceptible.
- Highly toxic to dogs (LD50 of 0.5–1.5 mg/kg of body weight) and cats (0.55 mg/kg of body weight)
- Naturally occurring feline aflatoxicosis has not been reported.

Risk Factors/Causes

- Outbreaks—accidental inclusion of contaminated corn during the manufacturing process or improper preparation of commercial dog foods
- Individual cases may occur following ingestion of moldy food (particularly bread).
- Warm humid conditions promote mold growth and aflatoxin production.
- Low moisture content in pet foods decreases the risk of mold growth.

Historical Findings

- Feeding moldy commercial pet food or ingesting other moldy foods such as bread
- Change in brands or recently opening a new bag of dog food
- Anorexia
- Depression
- Vomiting
- Polydipsia
- Polyuria
- Discoloration of the eyes and mucous membranes
- Initial signs are often vague and insidious in onset.
- Animals may exhibit an aversion to the contaminated food for several days prior to the development of clinical signs.



CLINICAL FEATURES

- Acute hepatic failure in multiple dogs from the same region or sharing the same food source should prompt a strong suspicion of aflatoxicosis.
- Severity of signs varies depending on the length of exposure and concentration of the aflatoxins ingested.
- Most often related to acute liver failure
 - Weakness
 - Depression
 - Anorexia
 - Vomiting
 - Diarrhea
 - Melena
 - Hematemesis
 - Abdominal distension
 - Icterus
 - Epistaxis
 - Bruising
 - Petechia
 - Peripheral edema
 - Seizures
 - DIC



DIFFERENTIAL DIAGNOSIS

- Rule out other causes of acute hepatic failure.
- Leptospirosis
- Hepatic abscess
- Bacterial cholangitis/cholangiohepatitis
- Liver lobe torsion
- Hepatic abscess
- Severe pancreatitis
- Xylitol toxicity
- Acetaminophen toxicity
- Sago palm toxicity
- Amanita mushroom toxicity
- Heavy metal toxicity
- Antifungal medications
- Phenobarbital
- Potentiated sulfonamides
- Tetracycline
- Idiosyncratic drug reactions
- Rat poisoning



DIAGNOSTICS

- Evaluate suspected feeds for the presence of aflatoxins, even if macroscopic evidence of mold is not detectable.
- Liver samples can be submitted for aflatoxin testing.
- Liver enzymes elevated
- Bilirubin increased
- Bile acids increased
- ACT, PT, and PTT often prolonged
- Antithrombin and protein C levels decreased; not specific to aflatoxicosis
- Dilute urine; granular casts may develop as toxicity progresses.

Pathological Findings

- No pathognomonic findings
- Hepatic cytology reveals microvesicular fatty vacuolation.
- Histologic findings include hepatic centrilobular necrosis, bile duct proliferation, fibrosis, hepatocellular fatty degeneration, and megalocytosis.
- Gross pathologic changes include generalized icterus, liver damage, ascites, widespread hemorrhage, and gallbladder edema.
- Renal proximal tubular necrosis has also been reported on histologic examination.



THERAPEUTICS

- There is no specific antidote.
- Treatment is directed toward limiting further hepatic injury, maximizing hepatic recovery, and supportive care.
- Intravenous fluids to correct dehydration, provide maintenance requirements and allow for ongoing losses

Drug(s) of Choice

- Evidence-based medicine to support therapies in clinically occurring aflatoxicosis are lacking.
- SAmE 20 mg/kg PO once a day on an empty stomach
- Synthetic colloids may be required in hypoalbuminemic patients.
- Metoclopramide (1–2 mg/kg per day IV as a CRI) starting at low doses and tapering upward to effect until vomiting is controlled
- Ondansetron (0.1–0.2 mg/kg IV as a slow bolus twice or four times a day) if metoclopramide is not effective
- Famotidine (0.5 mg/kg IV once to twice a day) if hematemesis or melena is present
- Sucralfate (0.5–1 g PO three times a day) if hematemesis or melena is present
- Packed red blood cells if significant hemorrhage is present or there are clinical signs associated with anemia
- Vitamin K1 may be helpful (0.5–1.5 mg/kg SQ or PO every 12 to 24 hours) if coagulation times prolonged
- Plasma transfusions to correct coagulopathies when present (10–15 ml/kg IV given over 2–4 hours)

Alternative Drugs

- Although unproven in dogs, milk thistle [(silibinin-phosphatidylcholine complex) 2–5 mg/kg PO once daily] may be beneficial.
- N-acetylcysteine may be hepatoprotective if SAmE cannot be given (140 mg/kg IV given slowly as a loading dose followed by 70 mg/kg every 6 hours until SAmE can be given orally); administer via a microfilter.

Diet

- Parenteral nutrition may be required with protracted vomiting.



COMMENTS

- Save samples (air tight containers or frozen) of suspect foods and GI contents for analysis.

- Save package information (product and date codes) to expedite proper identification of contaminated foods.
- Proper authorities should be contacted (product manufacturer and FDA consumer complaints coordinator or equivalent) if intoxication is linked to commercial pet foods.

Patient Monitoring

- Monitor for hypoalbuminemia and coagulopathies.
- Serially evaluate hepatic parameters to help guide therapy and determine prognosis in response to therapy.
- Serum electrolytes and the hematocrit

Prevention/Avoidance

- Discontinue all commercial dog foods and consider boiled rice and chicken until clinical signs of toxicity resolve.
- Avoid grossly moldy, discolored, or malodorous dog foods.

Possible Complications

- Aflatoxins are carcinogenic and immunosuppressive following chronic exposure.
- Long-term complications may include hepatic cancer and chronic liver failure.

Expected Course and Prognosis

- Prognosis varies with amount of toxin ingested and length of exposure.
- Prognosis is guarded to poor if signs of hepatic failure develop.
- Animals that recover will often do so within 3 to 5 days.
- Aflatoxins may bind albumin and have delayed toxic effects; administration of oral hepatoprotectants for up to 60 days has been suggested.

Abbreviations

- ACT: activated clotting time
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- DNA: deoxyribonucleic acid
- FDA: Food and Drug Administration
- GI: gastrointestinal
- IV: intravenously
- LD50: lethal dose that kills 50 percent of animals tested
- PO: by mouth
- PT: prothrombin time
- PTT: partial thromboplastin time
- RNA: ribonucleic acid

- SAME: s-adenosylmethionine
- SQ: subcutaneously

Suggested Reading

- Leung, MCK, Diaz-Llano, G, and Smith, TK. Mycotoxins in pet food: A review on worldwide prevalence and preventive strategies. *J Agric Food Chem* 2006;54:9623–9635.
- Newman, SJ, Smith, JR, Stenske, KA, et al. Aflatoxicosis in nine dogs after exposure to contaminated commercial dog food. *J Vet Diagn Invest* 2007;19:168–175.
- Stenske, KA, Smith, JR, Newman, SJ, et al. Aflatoxicosis in dogs and dealing with suspected contaminated commercial foods. *J Am Vet Med Assoc* 2006;228:1686–1691.
- Puschner, B. Mycotoxins. *Vet Clin Small Anim* 2002;32:409–419.

Author: Søren Boysen

Mycotoxins—Tremorgens



DEFINITION/OVERVIEW

- Fungal metabolites found in moldy foods and garbage that can induce signs of CNS excitation when ingested



ETIOLOGY/PATHOPHYSIOLOGY

- Ingested and absorbed via the GI tract
- Excretion in the bile, enterohepatic recirculation, and continued reabsorption may prolong the signs of toxicity.
- Two known tremorgens reported to cause toxicity in dogs: penitrem A and roquefortine C, both are produced by *Penicillium* spp. of fungi.
- The two mycotoxins may act synergistically if ingested together.

Systems Affected

- Neuromuscular—Exact mechanism of action unknown, although interference with neurotransmitter release at central and peripheral nerve synapses is suspected
- GI—Secondary to an unknown mechanism of action of the mycotoxins or the result of ingesting other vomitogenic materials in conjunction with the mycotoxins



SIGNALMENT/HISTORY

- One of the more common intoxications occurring naturally in dogs
- Probably underdiagnosed in the veterinary profession
- No known cases reported in cats

Risk Factors/Causes

- Free-roaming dogs that have access to garbage are likely to be at higher risk.

Historical Findings

- Ingestion of moldy foods or garbage, including dairy products, nuts, grains, bread, and pasta

- Weakness
- Panting
- Vocalization
- Ataxia
- Tremors
- Vomiting
- Owners typically report signs within 1 to 3 hours of garbage ingestion.



CLINICAL FEATURES

- Ingestion of the toxin may not be witnessed.
- Diagnosis often based on possible exposure, history, clinical signs, and response to treatment
- Should be suspected following acute onset of CNS stimulation and vomiting following ingestion of garbage
- Symptoms vary depending on the concentration of the mycotoxin present in the food and the amount of toxin ingested.
- Ataxia
- Tremors
- Hyperesthesia
- Hyperextension of the limbs
- Muscle contractions
- Seizure-like activity
- Hyperthermia
- Salivation
- Vomiting (often reported as black and tarry)
- Panting



DIFFERENTIAL DIAGNOSIS

- Other common neurologic toxins:
 - Strychnine
 - Metaldehyde
 - Pyrethroids
 - Organophosphates
 - Carbamates
 - Methylated xanthines (caffeine, theophylline, theobromine)
 - Lead
- Other less common neurologic toxins:
 - Bromethalin rodenticides
 - Hexachlorophene

- Chlorinated hydrocarbons
- Zinc phosphide
- The insecticide diethyltoluamide

Nontoxin induced causes of tremors and seizures:

- Cerebellar disorders
- Tremor syndrome of white dogs (Little White Shakers)
- Hypomyelination
- Dysmyelination
- Metabolic disorders
- Infectious diseases



DIAGNOSTICS

- Laboratory analysis of the vomit, stomach/intestinal contents, or gastric lavage contents of suspected animals provides a definitive diagnosis.
- Moldy food samples can also be submitted for tremorgenic toxin analysis.
- Screen for other common neurologic toxins if tremorgenic toxins are not confirmed on laboratory analysis.
- The minimum database should include a complete blood count, biochemistry panel, and urinalysis to rule out other causes of tremors and seizures.
- Increased levels of serum aspartate aminotransferase and creatinine kinase have been reported with tremorgenic mycotoxicosis, which occurs secondary to increased muscle activity.

Pathological Findings

- There are no typical findings on gross or histologic examinations.



THERAPEUTICS

- The goals of therapy are to minimize absorption of the mycotoxin from the GI tract, control the tremors and seizures, and provide supportive care.
- Induction of vomiting, gastric lavage, and activated charcoal may limit GI absorption but should only be performed in dogs that are not at risk for aspiration pneumonia.
- Active cooling (application of soaked towels and the use of fans) should be initiated if the temperature is greater than 41° C (stop active cooling efforts when the temperature falls to 39.5° C to avoid overshoot hypothermia, and monitor the patient closely to identify the development of hypothermia or recurrent hyperthermia).
- Intravenous fluids should be provided to maintain normal hydration status.

Drug(s) of Choice

- Pentobarbital (3–15 mg/kg IV administered to effect) and methocarbamol (55–220 mg/kg IV administered slowly to effect at a rate <200 mg/min) are currently recommended to control tremor-like activity.
- Pentobarbital can cause heavy sedation and appropriate monitoring is required.
- Methocarbamol provides muscle relaxation.

Precautions/Interactions

- Aspiration pneumonia may occur prior to or during therapy, especially following sedation to control tremors.
- Animals with active tremors and seizures should not have gastric lavage or activated charcoal administered until CNS excitement can be controlled.
- If medications to control the CNS excitement cause severe sedation and suppression of the gag reflex, administration of activated charcoal and gastric lavage should be approached with great care due to the risk of aspiration pneumonia.

Alternative Drugs

- Diazepam can be tried, however, when given alone it may be insufficient at controlling severe mycotoxin induced tremors.



COMMENTS

- Perform gastric lavage only under general anesthesia with cuffed endotracheal tube in place to prevent aspiration of gastric contents.
- Some affected animals can be intubated with minimal sedation.
- Patients under anesthesia should be endotracheally intubated and often require ventilation (monitor respiratory function).
- Activated charcoal can be administered by orogastric tube.

Patient Monitoring

- Monitor for continued tremor activity for at least 24 hours and treat as needed.
- Monitor temperature: hyperthermia may occur with uncontrolled tremors or hypothermia may develop following pentobarbital administration and subsequent sedation.
- Monitor respiratory rate and effort, level of sedation, and the presence or absence of a gag reflex following administration of pentobarbital and other sedatives.
- Arterial or venous blood gas analysis should be performed to evaluate acid-base status and carbon dioxide levels if there are concerns of hypoventilation.
- Thoracic radiographs and arterial blood gas analysis should be performed if there is a suspicion of aspiration pneumonia.

Prevention/Avoidance

- Proper disposal of moldy food products and preventing animals from accessing garbage will decrease occurrence of tremorgenic mycotoxicosis.

Expected Course and Prognosis

- Varies with the severity of symptoms and promptness of therapy
- Most dogs make a complete recovery within 2 to 3 days.
- Death has been reported in severe cases with uncontrollable convulsions.
- Concurrent aspiration pneumonia can contribute to significant morbidity and mortality and every precaution should be undertaken to avoid this complication.

Abbreviations

- CNS: central nervous system
- GI: gastrointestinal
- IV: intravenously

Suggested Reading

- Boysen, SR, Rozanski, EA, Chan, DL, et al. Tremorgenic mycotoxicosis in four dogs from a single household. *J Am Vet Med Assoc* 2002;221:1441–1444.
- Puschner, B. Mycotoxins. *Vet Clin Small Anim* 2002;32:409–419.
- Young, KL, Villar, D, Carson, TL, et al. Tremorgenic mycotoxin intoxication with penitrem A and roquefortine in two dogs. *J Am Vet Med Assoc* 2003;222:52–53.

Author: Søren Boysen

Noncardiogenic Pulmonary Edema



DEFINITION/OVERVIEW

- The accumulation of abnormal fluid and solutes in the pulmonary interstitium and alveoli in the absence of heart disease



ETIOLOGY/PATHOPHYSIOLOGY

- Common cause of all forms: increased pulmonary vascular permeability, associated with leakage of fluid, proteins, and other solutes into the interstitium and alveoli
- Several proposed mechanisms depending on underlying cause:
 - Massive sympathetic discharge causes release of catecholamines, leading to systemic vasoconstriction, increased afterload, and temporary shunting of blood into the pulmonary circulation, this leads to transient pulmonary circulatory overload and endothelial damage; proposed mechanism for neurogenic edema, electric cord bites, and upper airway obstruction
 - Severe decrease in intrathoracic pressure induced by inspiratory attempts against an airway obstruction; proposed mechanism for upper airway obstruction
 - Hypoxia leads to pulmonary vasoconstriction and increased permeability of microvasculature.
 - Direct chemical or inflammatory mediator damage (circulating histamine, complement, cytokines, or inhaled/ingested toxins) leads to endothelial damage and increased pulmonary vasculature permeability.
- For all forms, the inciting insult may trigger an inflammatory response cascade that often worsens in the first 24 hours after the initial episode; the most severe form is known as ARDS.
- Severity of clinical manifestation varies ranging from mild to severe; the most seriously affected patients may progress from normal to death in as little as a couple of hours after the incident.
- Overall incidence/prevalence is uncommon

Systems Affected

- Respiratory—decreased compliance, atelectasis, decreased FRC, tracheal narrowing
- Hemic/lymphatic/immune—if severe and causing respiratory failure, may be associated with DIC and hypoproteinemia due to loss of protein into the pulmonary parenchyma

- Cardiovascular—hypotension, tachycardia, other dysrhythmias, and shock
- Renal/Urologic—acute renal failure



SIGNALMENT/HISTORY

- Species: mainly dogs, occasionally cats
- No confirmed breed or sex predilection; brachycephalic dogs are more prone to airway obstruction.
- Higher incidence in puppies younger than 1 year old
- Young animals—associated with strangulation, head trauma, and electric cord bites
- Old—associated with laryngeal obstruction, neoplasia, and seizures
- No known genetic basis for the disease
- Respiratory signs vary depending on underlying cause and severity.

Risk Factors/Causes

- Hypoproteinemia
- Crystalloid fluid resuscitation
- Upper airway obstruction—brachycephalic, laryngeal paralysis; leash/choke-chain/strangulation injury; mass lesion; abscess; or other temporary airway obstruction
- Electric shock
- Acute neurologic disease—head trauma; prolonged seizures
- Pulmonary and other neoplasia
- Drugs (i.e., ketamine, other anesthetics)
- Chemicals (i.e., chlorine, minoxidil, waterproofing hydrocarbons)
- Blood transfusions (including human albumin in healthy dogs)
- Uremic toxins
- SIRS—sepsis, pancreatitis, and endotoxemia
- Smoke inhalation
- Anaphylaxis (cats)
- Hyperosmolar fluid/sea water inhalation/near drowning

HISTORICAL FINDINGS

- Predisposing cause
- Acute onset of respiratory distress



CLINICAL FEATURES

- Mild to severe respiratory distress
- Increased respiratory rate and effort; open-mouthed breathing

- Postural adaptations to respiratory distress in severe cases (e.g., orthopnea, neck extension)
- Restlessness, unwillingness to lie down
- Pale or cyanotic mucous membranes (severe)
- Harsh lung sounds (early, mild) or generalized crackles (late, severe) on auscultation
- Expectoration of pink froth or bubbles in severely affected animals; in intubated patients, large volumes of bloody fluid can flow out through the endotracheal tube.
- Normal cardiac auscultation; may note dysrhythmias; tachycardia common
- Possible oral burns if due to electric shock



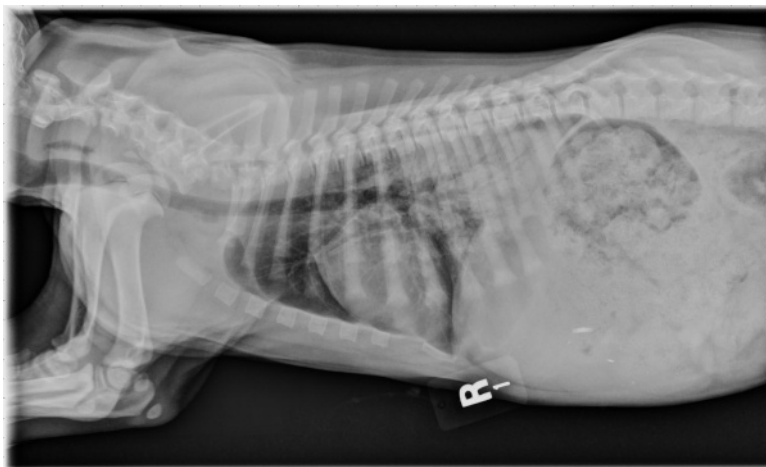
DIFFERENTIAL DIAGNOSIS

- Cardiogenic pulmonary edema
- Pulmonary infection—bacterial, viral, or fungal pneumonia
- Pulmonary neoplasia
- Pulmonary hemorrhage
- Pulmonary thromboembolism
- Many of the above can occur concurrently with noncardiogenic pulmonary edema.



DIAGNOSTICS

- CBC—leukocytosis but possibly leukopenia and thrombocytopenia, owing to neutrophil sequestration in the lung and platelet consumption
- Biochemistries—usually normal; may note hypoalbuminemia owing to pulmonary protein loss; mild hyperglycemia reported
- Urinalysis—usually normal
- Arterial blood gas analysis—usually demonstrates mild to severe hypoxemia and hypocapnia; results are not specific but indicate the severity of pulmonary dysfunction
- Coagulation testing (severely affected patients)—may reveal mild to moderate prolongation of PT and PTT because of consumption of coagulation factors and DIC
- Thoracic radiographs—vital; may simply reveal prominent interstitial pattern with mild or early disease; may note alveolar infiltrates with moderate or severe disease; alveolar infiltrates in the dorsocaudal lung fields common; alveolar infiltrates may be seen in other lung fields, are often asymmetrical and may demonstrate predominant right-sided involvement (See Figure 68.1)
- Echocardiography—rule out cardiogenic pulmonary edema
- Computed tomography—optional to rule out differential diagnoses such as pulmonary neoplasia or thromboembolism, however may be contraindicated due to need for anesthesia



■ **Figure 68.1** Right lateral thoracic radiograph of 15-week-old puppy with noncardiogenic pulmonary edema secondary to strangulation.

- Pulse oximetry—noninvasive, continuous monitoring of arterial hemoglobin saturation; provides information about the severity and progression of pulmonary dysfunction
- Pulmonary artery wedge pressure—confirms noncardiogenic origin; uncommonly used in small animal clinical patients
- ETL, TTW or BAL—if it can be safely performed, may demonstrate neutrophilic inflammation and cytologic evaluation may help rule out pneumonia of bacterial or fungal origin; culture can confirm presence or absence of infection.

Pathologic Findings

- Lungs—may be heavy, red, or congested; may fail to collapse; may exhibit a wet cut surface; may note foam in the major airways
- Histopathologic—depend on severity of the insult; early, mild: may note eosinophilic amorphous material filling the alveoli or may be near normal because fluid removed in processing; severe: alveolar hyaline membranes, alveolitis, and interstitial inflammatory infiltrates with neutrophils and macrophages evident and accompanied by atelectasis, vascular congestion, and hemorrhage; may be found only hours after a severe insult



THERAPEUTICS

- Inpatient versus outpatient—depends on the severity of respiratory dysfunction and cause (e.g., dogs with upper airway obstruction, severe seizures, or pancreatitis may require hospitalization)
- Treat the underlying cause (e.g., relieve airway obstruction or treat seizures)

- Mild to moderate—patients generally improve on their own within 24 to 48 hours with complete resolution; offer support of pulmonary and cardiovascular function while the lung repairs
- Severe—difficult to treat; may require PPV because of respiratory failure, plasma transfusions to treat DIC; many die despite extensive supportive care
- Damaged endothelium in the pulmonary vasculature—no specific treatment available
- Inflammatory response—generated by a variety of mediators and cascades; cannot be blocked by one specific anti-inflammatory drug that leads to resolution of the edema
- Oxygen therapy—vital in moderate to severe disease; administer via a mask or hood, oxygen concentration depends on the severity of disease; most patients do well on 40 to 50 percent oxygen, but severe disease may require 80 to 100 percent to sustain life
- Fluid therapy with a balanced electrolyte—give as replacement solution with dehydration or shock
- Plasma or synthetic colloids—consider with hypoproteinemia, coagulopathy, or to improve oncotic pressure, minimizing movement of fluid into the lungs

Drug(s) of Choice

- Diuretics—often ineffective; edema caused by changes in permeability not high hydrostatic pressure; may use furosemide cautiously in boluses of 0.5 to 2.0 mg/kg IV, IM or at 0.1 to 1 mg/kg per hour IV in a continuous infusion
- Corticosteroids—minimize airway swelling in animals with upper airway obstruction; generally ineffective for pulmonary inflammatory response; may predispose patients to infectious complications (e.g., bacterial pneumonia); if used, recommend an anti-inflammatory dosage of a short-acting drug (e.g., dexamethasone sodium phosphate at 0.1–0.2 mg/kg IV)

Precautions/Interactions

- Minimize stress in animals with respiratory distress.
- Severe—may require PPV and PEEP
- Aggressive fluid therapy can worsen pulmonary edema: increased circulating volume results in increased hydrostatic pressure in the pulmonary microvasculature, worsening the pulmonary vascular leakage.
- Excessive use of diuretics may cause dehydration and a marked decrease in intravascular volume with minimal resolution of edema that may exacerbate cardiovascular collapse or shock.

Activity

- Rest and minimal stress vital for minimizing oxygen requirements in moderately to severely affected animals

Surgical Considerations

- Relevant only for treating the underlying cause



COMMENTS

Client Education

- Warn client that the condition may worsen before improving.
- Inform client that severe disease, which progresses rapidly to fulminant pulmonary edema and respiratory failure, is associated with a very poor prognosis.

Patient Monitoring

- Observe respiratory rate and pattern and auscultate frequently (every 2–4 hr) for the first 24 to 48 hours.
- Assess pulmonary function by pulse oximetry or arterial blood gas analysis (initially every 2–4 hr).
- Perform PCV and total solids and evaluate mucous membranes, pulse quality, heart rate, ECG, blood pressure, and urine output every 2 to 4 hours to assess cardiovascular status and progression to shock.
- In severely affected animals, monitor renal function, coagulation status, and white blood cell count.
- Recheck thoracic radiographs to evaluate resolution and monitor for other contributing pulmonary disease.

Prevention/Avoidance

- Avoid contact with electric wire.
- Correct airway obstruction.
- Treat seizures or high intracranial pressure.

Possible Complications

- Usually none if patient recovers from acute crisis

Expected Course and Prognosis

- Mild to moderate—uneventful resolution of signs in 24 to 72 hours; no specific treatment required except for oxygen and careful fluid supplementation
- Severe—progression to ARDS usually results in mortality within 1 to 2 days
- Overall survival rates—80 to 100 percent. In electric shock, mortality up to 40 percent in dogs if severe, cats typically excellent prognosis
- Long-term prognosis—excellent for recovered patients

Synonyms

- Capillary leak syndrome
- Permeability edema

Abbreviations

- ARDS: acute respiratory distress syndrome
- BAL: bronchoalveolar lavage
- CBC: complete blood count
- DIC: disseminated intravascular coagulation
- ECG electrocardiogram
- ETL: endotracheal lavage
- FRC: functional residual capacity
- IM: intramuscularly
- IV: intravenously
- PCV: packed cell volume
- PEEP: positive end-expiratory pressure
- PPV: positive pressure ventilation
- PT: prothrombin time
- PTT: partial thromboplastin time
- SIRS: systemic inflammatory response syndrome
- TTW: transtracheal wash

See Also

- Acute respiratory distress syndrome (ARDS)

Suggested Reading

- Drobatz, KJ, and Concannon, K. Noncardiogenic pulmonary edema. *Comp Contin Educ Pract Vet* 1994;16:333–346.
- Drobatz, KJ, Saunders, HM, Pugh, C, and Hendrick, JC. Noncardiogenic pulmonary edema 26 cases (1987–1993). *J Am Vet Med Assoc* 1995;206:1732–1736.
- Kerr, LY. Pulmonary edema secondary to upper airway obstruction in the dog: a review of nine cases. *J Am Anim Hosp Assoc* 1989;25:207–212.
- Kolata, RJ, and Burrows, CF. The clinical features of injury by chewing electrical cords in dogs and cats. *J Am Anim Hosp Assoc* 1981;17:219–222.

Authors: Dorothy M. Black and Lesley G King

Organophosphate Toxicity



DEFINITION/OVERVIEW

- OPs and CMs are anticholinesterase chemicals used most commonly as household and industrial insecticides; they can cause toxicity in humans and veterinary species.
- OP exposure in dogs and cats is by ingestion, dermal contact, or inhalation.
- The dose required for OP intoxication and lethality varies significantly by specific compound.



ETIOLOGY/PATHOPHYSIOLOGY

- OP and CM compounds cause toxicity by inhibiting the action of acetylcholinesterase at neuronal synapses and the neuromuscular junction. Acetylcholinesterase is the enzyme that degrades acetylcholine, and thus prevents overstimulation of neurons and muscles for which acetylcholine is a neurotransmitter. Acetylcholine plays a stimulatory role at the skeletal neuromuscular junction, the parasympathetic neuromuscular junction, synapses of the autonomic nervous system, and some areas of the CNS. Inhibition of acetylcholinesterase leads to overstimulation of the skeletal neuromuscular junction, parasympathetic system, and occasionally the sympathetic nervous system and can have variable effects on the CNS. Thus, clinical signs of acute OP or CM toxicity in dogs and cats involve skeletal muscle, the parasympathetic nervous system, and the CNS.
- OP and CM compounds are available in many housepets' environments. These chemicals are used commonly in household insecticides, mixed fertilizer/insecticide preparations, and in some over-the-counter flea and tick products for topical use directly on dogs and cats. Both dogs and cat are susceptible to intoxication.
- OPs are most commonly associated with acute toxicity as described here. However, OPs have also been associated with OP-induced delayed neuropathy and the intermediate syndrome, both of which are uncommon. More information on these syndromes in dogs and cats is available elsewhere (see *Suggested Reading*).

Systems Affected

- Nervous—Muscle tremors and twitching are common. Eventually, weakness to paralysis may occur. Obtundation is common; seizures to coma can be seen in severe cases.

- Cardiovascular—Bradycardia is common. Rarely, tachyarrhythmias may occur.
- Gastrointestinal—Hypersalivation, vomiting, diarrhea, and abdominal pain are common. Rarely, acute pancreatitis may occur in the dog.
- Ophthalmic—Miosis is common, and can help distinguish OP or CM intoxication from that caused by other tremorgens. Lacrimation (excessive tearing) may also be present.
- Respiratory—Occasionally, intoxicated patients may have severe bronchoconstriction and bronchorrhea (excessive bronchial secretions), which can lead to respiratory distress and life-threatening hypoxemia. Diaphragmatic function may be impaired in severe cases.



SIGNALMENT/HISTORY

- Both dogs and cats of all ages and breeds are susceptible to OP and CM intoxication.
- Clinical signs usually occur within 30 minutes to 6 hours after chemical ingestion or inhalation.
- Time for dermal absorption can vary, but clinical signs may be present within a few hours.
- Clients may be aware of OP or CM exposure, such as in the case of purposeful topical insecticide application on the animal. However, clients may still answer “No” when asked generally if toxins are available in the environment, even when the exposure was through bathing or insecticide in the garden. Therefore, when the clinician has a high index of suspicion for OP or CM toxicity based on physical examination, it may be helpful to ask the client specific questions about flea and tick treatments, exposure to public gardens, and chemical use in the yard.

Risk Factors/Causes

- Household insecticides, garden insecticides, and chemicals used to topically treat flea or tick infestation on dogs and cats are the most common sources of exposure to OPs and CMs for housepets.

Historical Findings

- Occasionally clients are aware of historical application of a topical insecticide or exposure to environmental insecticide products.
- More commonly, dogs and cats with OP or CM toxicity are presented with complaints of acute muscle tremors, ataxia, hypersalivation, or gastrointestinal disturbance of unknown etiology.



CLINICAL FEATURES

- Physical examination most commonly reveals generalized muscle tremors; seizures to coma may be present.
- Clinical signs of parasympathetic overdrive are common, and include DUMBELS:
 - D: diarrhea
 - U: urination
 - M: miosis
 - B: bradycardia/bronchospasm
 - E: emesis
 - L: lacrimation
 - S: salivation
- Bronchospasm and excessive bronchial secretions can lead to life-threatening hypoxemia.
- Organophosphate or CM intoxication should be considered a top rule out in patients with acute onset generalized tremors in combination with these parasympathetic signs.
- Not all signs are present in all patients.



DIFFERENTIAL DIAGNOSIS

- Some other toxins that can cause similar clinical signs include serotonergics; Penitrem A, roquefortine, and other mycotoxins; metaldehyde; strychnine; many toxic plants; nicotine; some illicit drugs; and pyrethrins and some other insecticide compounds.
- Other differentials for OP or CM toxicity include nontoxic conditions such as inflammatory, infectious, idiopathic, and degenerative diseases of the CNS; neuromuscular diseases; and metabolic diseases that affect the neurologic system.



DIAGNOSTICS

- A tentative diagnosis can be made through consideration of signalment and historical data in combination with physical examination findings.
- Clinicopathologic data are nonspecific and therefore generally noncontributory; abnormalities can include azotemia, hematuria, leukocytosis, elevated serum creatine kinase concentration, hypokalemia, and hyperglycemia.
- Whole blood can be submitted to determine blood cholinesterase activity; activity < 50 percent is suspicious for intoxication, whereas activity <25 percent is confirmatory.
- Definitive diagnosis requires toxicologic examination of blood, gastric contents, urine, or source material. Contact a veterinary toxicology laboratory to confirm

sample handling procedures for whole blood cholinesterase activity and toxin identification.



THERAPEUTICS

- Supportive care is imperative for the intoxicated patient.
- Oxygen should be supplemented to animals with respiratory distress or tachypnea. Patients with severe hypoxemia or poor diaphragmatic function (and subsequent hypoventilation) are at high risk of immediate death, and should be tracheally intubated and positive-pressure ventilated.
- Intravenous fluid therapy is required for hypovolemia or dehydration, which can occur due to vomiting, diarrhea, or sustained muscle activity.
- Seizures should be treated immediately.
- Antiemetics and gastric protectants may be considered for those with severe gastrointestinal disturbance.
- Recumbent patients should be turned every 4 to 6 hours to prevent pressure sores, and oral care procedures and intubation may be required to help decrease risk of aspiration.
- Decontamination strategies should be used to decrease systemic absorption of OP or CM toxins, when possible.
 - Induction of vomiting is important for animals that have ingested toxin within the past 1 to 2 hours but is less useful in animals whose exposure occurred prior to that time.
 - Animals with neurologic abnormalities and those that have already vomited should not be made to vomit.
 - Activated charcoal is useful in OP and CM intoxication, though the risks of aspiration in animals with clinical signs must be weighed against the benefits.
 - Patients with the potential for topical exposure should be bathed with mild soap and water as soon as their clinical condition allows; they should be dried completely to prevent hypothermia. Patients with topical exposure may also benefit from gastrointestinal decontamination because they may have ingested some toxin during grooming, and enterohepatic circulation of the systemic toxin can occur even if initial exposure is topical.
- Antidotes are available for the muscarinic (parasympathetic) and nicotinic (skeletal muscle) signs of OP and CM toxicity. They can be used in addition to, but cannot replace, supportive care and good clinical judgment.

Drug(s) of Choice

- Supportive care should be provided, as clinically indicated, with supplemental oxygen, intravenous fluids, and gastrointestinal support.
- Seizures should be treated with diazepam 0.5 to 1 mg/kg (0.23–0.45 mg/lb) IV or another benzodiazepine at an appropriate dose.

- Activated charcoal can be administered at 1 to 4 g/kg (0.45–1.8 g/lb) and may be given once or repeated every 6 hours for the first day after exposure to bind any enterohepatically circulated toxin. If repeated doses are administered, cathartics such as sorbitol should be avoided to help prevent electrolyte and acid-base abnormalities.
- Atropine is the most useful antidote and is used to treat the potentially life-threatening muscarinic signs of bradycardia, bronchospasm, and excessive bronchial secretions. The initial atropine dose of 0.1 to 2 mg/kg (0.05–0.91 mg/lb) should be given one-fourth IV and the remainder SQ. The dose is based on severity of the muscarinic signs. Adequate treatment leads to clinical signs of atropinization: mydriasis, dry mouth, and mild sinus tachycardia. Depending on the severity of intoxication, atropine may need to be repeated every 20 to 30 minutes at smaller doses of 0.1 to 0.25 (0.05–0.11 mg/lb) to achieve or maintain atropinization.
- 2-PAM is an antidote for the nicotinic signs of acute, moderate to severe OP or CM toxicity. It has little impact on CNS or muscarinic signs. The efficacy of 2-PAM is debated, and the drug may be most beneficial with concurrent atropinization. 2-PAM can worsen clinical signs of mild OP or CM toxicity, so is not recommended in those cases. Patients should be monitored closely during 2-PAM administration and the drug discontinued if clinical signs worsen during treatment. The 2-PAM dose is 10 to 20 mg/kg (4.5–9.1 mg/lb) SQ or as a slow intravenous infusion every 12 hours. Refer to the package insert for information on drug compatibility and administration.

Precautions/Interactions

- Emesis should *not* be induced if ingestion occurred more than 2 hours prior; if the animal has neurologic impairment or other cause for increased risk of aspiration or if the animal has already vomited.
- Patients that present with tachycardia or tachyarrhythmia rather than the classic bradycardia should be monitored closely if they require atropinization for bronchospasm or bronchial secretions (this seems an unlikely scenario).
- Animals with bradycardia should probably not be treated with medications known to cause bradycardia (i.e., opiates, anesthetics) until they have been atropinized and have normal heart rates.
- The major precaution when treating a patient with 2-PAM is that it may exacerbate clinical signs of intoxication, in which case it should be discontinued.

Alternative Drugs

- Glycopyrrolate may be used if atropine is not available, though it has a slower onset of action than atropine. An appropriate starting dose would be 0.05 mg/kg (0.02 mg/lb) IV.



COMMENTS

Client Education

- All OPs and CMs should be removed from the pet's environment.

Patient Monitoring

- Patients should be monitored closely in hospital for resolution or worsening of muscarinic, nicotinic, and CNS signs.
- Vital signs should be checked frequently, and a continuous ECG is helpful to monitor for brady- or tachycardia.
- Blood pressure should be measured until the animal is stabilized.
- Pulse oximetry or PaO₂ may be used to assess patient oxygenation status, and arterial or venous PCO₂ can be used to check for hypoventilation due to diaphragmatic weakness.
- Time to resolution varies by severity of intoxication, but usually takes 1 to 3 days if the patient is adequately decontaminated.
- Once the animal is home, further monitoring is generally not required as long as the toxic source is removed from the environment.

Prevention/Avoidance

- All OPs and CMs should be removed from the pet's environment.

Possible Complications

- Acute OP toxicity has been associated with acute pancreatitis in humans. There is evidence that it could cause acute pancreatitis in dogs but probably not in cats.
- Other complications could include development of intermediate syndrome following the acute crisis or more typical complications such as aspiration pneumonia from hypersalivation or vomiting.

Expected Course and Prognosis

- Clinical course depends on the severity of intoxication and varies from mild clinical signs with need for only brief observation to a severe clinical syndrome with need for longer hospitalization, mechanical ventilation, and a high risk of death. Regardless of initial clinical course, if the animal survives the acute crisis, prognosis for full recovery is good, as development of intermediate syndrome appears to be rare in dogs and cats.

Synonyms

- Anticholinesterase intoxication or toxicity; carbamate intoxication or toxicity.

Abbreviations

- CM: carbamate
- CNS: central nervous system
- ECG: electrocardiogram
- IV: intravenously
- OP: organophosphate
- PaO₂: partial pressure of oxygen in arterial blood
- PCO₂: partial pressure of carbon dioxide in blood
- SQ: subcutaneously
- 2-PAM: 2-pyridine aldoxime methiodide

Suggested Reading

- Blodgett, DJ. Organophosphate and carbamate insecticides. In: Peterson, ME and Talcott, PA, eds. *Small Animal Toxicology*, 2nd ed., pp. 941–955. St. Louis: Saunders Elsevier, 2006.
- Burkitt, JM. Anticholinesterase intoxication. In: Silverstein, DC and Hopper, K, eds. *Small Animal Critical Care Medicine*, pp. 387–391. St. Louis: Saunders Elsevier, 2009.
- Ellenhorn, MJ, Schonwald, S, Ordog, G, and Wasserberger, J. Pesticides. In: Ellenhorn, MJ, Schonwald, S, Ordog, G, and Wasserberger, J, eds. *Ellenhorn's Medical Toxicology: Diagnosis and Treatment of Human Poisoning*, 2nd ed., pp. 1614–1631. Baltimore: Williams & Wilkins, 1997.
- Taylor, P. Anticholinesterase agents. In: Brunton, LL, Lazo, JS, and Parker, KL, eds. *Goodman & Gilman's The Pharmacological Basis of Therapeutics*, 11th ed., pp. 201–216. New York: McGraw-Hill Companies, 2006.

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Pancreatitis



DEFINITION/OVERVIEW

- Acute pancreatitis—pancreatic inflammation that occurs suddenly.
- Chronic pancreatitis—pancreatic inflammation that persists and often causes permanent morphologic change (i.e., exocrine pancreatic insufficiency).
- Pancreatic abscess—in dogs: typically sterile; in cats: may be sterile or septic.



ETIOLOGY/PATHOPHYSIOLOGY

- Host defense mechanisms normally prevent pancreatic autodigestion by pancreatic enzymes, but under select circumstances these defenses fail; autodigestion occurs when digestive enzymes are activated within pancreatic acinar cells. Local and systemic tissue injury caused by released pancreatic enzymes and various inflammatory mediators (e.g., kinins, free radicals, complement factors).
- Causes in dogs: Dietary fat appears to be primary cause. Pancreatic trauma (e.g., iatrogenic at surgery, automobile associated), ischemia (e.g., due to shock), and drugs (e.g., azathioprine) seem less common. Hypercalcemia is uncertain cause. Causes of sterile pancreatic abscess uncertain, perhaps secondary to prior episodes which caused necrosis of nearby fat.
- Causes in cats: Infectious (e.g., toxoplasmosis, FIP), parasites (flukes), pancreatic duct obstruction, and extension of feline hepatobiliary inflammation are believed important.

Systems Affected

- GI—altered GI motility (ileus) from sterile, chemical peritonitis; local/generalized sterile peritonitis due to enhanced vascular permeability.
- Hepatobiliary—shock, pancreatic enzyme injury, and inflammatory cellular infiltrates may damage hepatocytes; intra/extrahepatic cholestasis possible.
- Cardiovascular—cardiac arrhythmias secondary to myocardial depressant factor.
- Hematology—SIRS due to excessive activation of systemic inflammatory and coagulation cascades; DIC may occur.
- Respiratory—pulmonary edema, pleural effusion, and ARDS are uncommon but potentially fatal in patients with SIRS.



SIGNALMENT/HISTORY

Risk Factors/Causes

- Breeds at increased risk include miniature schnauzers, Yorkshire terriers, miniature poodles and Siamese cats, but any animal may be affected. Female dogs may have increased risk. Any age may be affected; middle aged to older dogs (i.e., >7 years) and cats may be at increased risk.
- Concurrent diseases: In dogs, diabetes mellitus, hyperadrenocorticism, and perhaps chronic renal failure. In cats, hepatobiliary tract disease.



CLINICAL FEATURES

Acute Pancreatitis

Historic Findings

- Lethargy, depression, and anorexia are common in dogs and cats. Signs may be peracute or chronic (e.g., weeks). In dogs, vomiting and abdominal discomfort are especially common; diarrhea and icterus are seen less frequently. In cats, history tends to be much vaguer than in dogs. Vomiting is much less prominent than in dogs.

Physical Examination Findings

- Dogs and cats typically evidence lethargy, depression, and dehydration.
- Dogs: Upper abdominal discomfort is frequent but icterus less common; fever infrequent, severe pancreatitis secondary to pancreatic carcinoma may cause sterile subcutaneous fat necrosis.
- Cats: Often hypothermic; abdominal discomfort may be very hard to detect unless very careful palpation is performed; icterus may occur.

Pancreatic Abscesses

Dogs

- Affected patients may have severe signs or may have chronic, mild, smoldering signs of vague GI upset (e.g., decreased appetite, intermittent vomiting).



DIFFERENTIAL DIAGNOSIS

- Dogs—Other causes of acute abdomen: GI tract foreign body with or without obstruction, severe gastroenteritis, GI tract perforation with septic peritonitis, gastric ulcer (with or without perforation), abdominal neoplasia. Hepatobiliary tract disease (especially inflammatory disease that causes icterus), hypoadrenocorticism, acute

renal failure, and anything causing severe abdominal inflammation (e.g., pyelonephritis, prostatitis, pyometra).

- Cats—Same as for dogs. Feline pancreatitis can be very vague, and almost any occult disease may mimic pancreatitis.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Dogs and cats: mild, moderate, severe, or no change in the leukogram. Inflammatory leukograms may be mature, regenerative, or degenerative; may/may not have toxic leukocytes: pancreatitis cannot be differentiated from septic disease based on CBC.
- Thrombocytopenia may occur in patients with DIC.
- Amylase and lipase are very nonspecific and insensitive; dogs with pancreatitis secondary to pancreatic carcinoma very rarely have astronomically high serum lipase values.
- Prerenal azotemia is common, and hepatic enzymes often increased, but, neither is specific for pancreatitis.
- Hyperbilirubinemia is primarily due to extrahepatic biliary tract obstruction but may be secondary to hepatocellular damage from direct damage (due to the proximity of the pancreas to the liver) or SIRS.
- Cats may be hypocalcemic (more obvious when measuring ionized calcium), but this is inconsistent. Hypocalcemia in cats with pancreatitis is a negative prognostic indicator.

Other Blood Tests

- TLI is best test for EPI; however, finding EPI in dog breeds that are not known to develop pancreatic acinar atrophy has been suggested to diagnose chronic pancreatitis (currently uncertain). Very high serum TLI in dogs suggests acute pancreatitis (can also be due to reduced glomerular filtration rate) but is a very insensitive test for pancreatitis.
- Serum TLI testing has poor sensitivity/specificity for pancreatitis in the cat.
- Pancreatic lipase immunoreactivity testing appears to be the most sensitive blood test in both dog (approximately 80 percent) and cat, but specificity for clinically significant inflammation is currently uncertain.

Imaging

- Abdominal radiographs—Poorly sensitive in dogs and cats. Affected dogs may have localized poor serosal contrast behind liver and in the upper right quadrant, static gas pattern in the proximal duodenum, widened angle between pyloric antrum and proximal duodenum. Valuable in helping eliminate diseases mimicking pancreatitis (e.g., foreign body).

- Abdominal ultrasound—very specific, but sensitivity depends on the species (more sensitive in dogs than cats) and operator. A hypoechoic pancreas surrounded by hyperechoic shadows with or without fluid or an enlarged pancreatic parenchyma is suggestive of pancreatitis. Extrahepatic biliary tract obstruction in the dog strongly implies pancreatitis. Ultrasonographic appearance of the pancreas can change dramatically within hours. Cystic lesions suggest pancreatic abscess and should be aspirated for cytology.
- Thoracic radiographs may reveal pleural effusion in cases with SIRS.

Pathologic Findings

- Dogs: Adhesions and saponified fat are common; pancreas may appear edematous, discolored (i.e., gray, necrotic), or hemorrhagic. Chronic pancreatitis may have scarring/fibrosis.
- Cats: Discolored with adhesions or may appear relatively normal. Nodular pancreatic hyperplasia may resemble pancreatitis. Cats are sometimes affected by lymphocytic-plasmacytic pancreatitis in addition to suppurative or necrotizing forms.
- Laparoscopic or surgical biopsy is more commonly performed in cats than dogs.



THERAPEUTICS

- No well-designed, prospective, stratified studies in spontaneously affected dogs or cats exist; therefore, current therapeutic recommendations are based on anecdotal evidence and personal experiences.

Dogs

- Aggressive fluid therapy appears important. Correct dehydration fully by slightly overestimating deficit (because underestimating dehydration is common). Give replacement fluids (e.g., lactated Ringer's solution, Normasol-R) with potassium supplementation as deemed appropriate from biochemistry panel monitoring at maintenance rates (40–60 ml/kg per day). Reassess patient's weight periodically to detect and replace ongoing losses.
- Hypoalbuminemic patients may benefit from colloids (e.g., hetastarch at 5–20 ml/kg per day).
- Use of plasma is debatable; if used, ideally monitor serum albumin concentration or antithrombin levels to determine when enough has been given.
- Oral food intake is initially withheld because fat exacerbates canine pancreatitis. Supply nutrients either enterally via enterostomy tube (e.g., jejunostomy or naso-jejunoscopy tube) or parenterally (e.g., peripheral parenteral nutrition). Use a fat-free diet (e.g., potato, rice) when oral food intake is restarted (e.g., no vomiting for at least 36–48 hours).

Drug(s) of Choice

- Antiemetics as needed: maropitant (1 mg/kg SQ every 24 hours), ondansetron (0.5–1 mg/kg IV every 12–24 hours), dolasetron (0.6–1 mg/kg IV every 24 hours), prochlorperazine (0.1–0.5 mg/kg IM or SQ every 8–12 hours).
- H₂ receptor antagonists for antidyspeptic action in nauseous patients: famotidine (0.5 mg/kg IV every 12–24 hours).
- Analgesics as needed: buprenorphine (0.005–0.01 mg/kg IM, IV, or SQ every 6–12 hours, hydromorphone 0.1 mg/kg SQ, IV, or IM every 6–8 hours, fentanyl 3–10 µg/kg per hour IV CRI).
- Antibiotics: controversial because septic pancreatitis is extremely rare in dogs. If deemed necessary: cefoxitin (30 mg/kg IV every 8 hours) or combination of ampicillin (22 mg/kg every 8 hours) plus enrofloxacin (10 mg/kg IV every 24 hours) is reasonable.
- FFP if DIC is present: give sufficient amounts to restore antithrombin III to reference range. Can give heparin concurrently (75–100 units unfractionated heparin SQ every 8 hours or 150 units low molecular weight heparin SQ every 8 hours) in animals that are not thrombocytopenic or hypocoagulable.
- Steroids: very controversial, may be used in patients with SIRS. Relative hypoadrenocorticism is suggested to occur in patients with severe inflammatory disease.

Precautions/Interactions

- Enrofloxacin should be diluted and given over 30 min when given IV.
- Azathioprine rarely causes pancreatitis.

Surgical Considerations

- Acute pancreatitis is not generally a surgical disease, and improper anesthesia may decrease visceral perfusion, which theoretically may exacerbate pancreatitis. Pancreatic abscesses may be drained percutaneously or surgically. Dogs with extrahepatic biliary tract obstruction rarely (if ever) need drainage or bypass or stent procedures; appropriate medical management almost always resolves the obstruction. Cholecystoduodenostomy should be avoided if possible because of associated morbidity.

Cats

- Therapy in cats is similar to that of dogs with the following exceptions: (a) Feline pancreatitis is not exacerbated by dietary fat; therefore, feed these patients as soon as possible with naso-esophageal, esophagostomy, or gastrostomy feeding tubes.
- In cats, septic pancreatitis occasionally occurs; antibiotics are more appropriate than in dogs.
- In cats, steroids might be valuable with lymphocytic pancreatitis.



COMMENTS

Client Education

- Guarded prognosis—Condition can worsen quickly and unexpectedly. Dogs that have pancreatitis once may be at increased risk for recurrence.

Patient Monitoring

- Hydration status (frequently by physical examination and body weight), plasma oncotic pressure (serum albumin concentration or COP as measured by a colloid osmometer, if available), electrolyte concentrations (especially potassium), urine output. Watch for SIRS or DIC.
- Clinical status is important in determining improvement during therapy; ultrasonographic appearance, TLI, and pancreatic lipase immunoreactivity currently are not clearly effective ways to monitor response to therapy.

Prevention/Avoidance

- In dogs: avoid high fat diets, especially if patient is at increased risk. Avoid unnecessary surgical manipulation of pancreas or poor fluid support during anesthesia, which decreases visceral perfusion.

Possible Complications

- SIRS, DIC, or extrahepatic biliary tract obstruction

Expected Course and Prognosis

- Depends on severity of disease—SIRS appears to be a negative prognostic sign.

Abbreviations

- ARDS: acute respiratory distress syndrome
- CBC: complete blood count
- COP: colloid oncotic pressure
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- EPI: exocrine pancreatic insufficiency
- FFP: fresh frozen plasma
- FIP: feline infectious peritonitis
- GI: gastrointestinal
- IM: intramuscularly
- IV: intravenously
- SIRS: systemic inflammatory response syndrome
- SQ: subcutaneously
- TLI: trypsin-like immunoreactivity

Suggested Reading

- Forman, MA, Marks, SL, DeCock, HEV, et al. Evaluation of serum feline pancreatic lipase immunoreactivity and helical computed tomography versus conventional testing for the diagnosis of feline pancreatitis. *J Vet Inter Med* 2004;18;807–815.
- Johnson, M, and Mann, F. Treatment for pancreatic abscesses via omentalization with abdominal closure versus open peritoneal drainage in dogs: 15 cases (1994–2004). *J Amer Vet Med Assoc* 2006;228:397–402.
- Kimmel, SE, Washabau, RJ, and Drobatz, KJ. Incidence and prognostic value of low plasma ionized calcium concentration in cats with acute pancreatitis: 46 cases (1996–1998). *J Amer Vet Med Assoc* 2001;219:1105–1109.
- Simpson, K. Feline pancreatitis. *Waltham Focus* 2005;15;13–19.

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Paraphimosis



DEFINITION/OVERVIEW

- Paraphimosis is the inability to retract the erect or nonerect extruded penis into the preputial sheath. It must be differentiated from priapism, which is a state of continuous erection usually due to neurologic abnormality (Figure 71.1). Paraphimosis of the erect penis is an emergency condition because constriction of venous blood flow will lead to greater engorgement, necrosis, damage to urethra, and gangrene. Chronic extrusion of the penis from the prepuce leads to drying, desiccation, licking, and trauma.



■ **Figure 71.1** Paraphimosis in a young dog. This patient was treated with cool sugar solution placed on the penis, lubrication of the penis with sterile lubricant, retraction of the edges of the prepuce to prevent the preputial orifice from inverting during replacement of the penis, and a small incision in the preputial orifice that was subsequently repaired with sutures and a purse-string suture.



ETIOLOGY/PATHOPHYSIOLOGY

- Causes include chronic licking, sexual excitement, balanoposthitis, entrapment of penis outside prepuce during detumescence, neurologic disease (intervertebral disc herniation, encephalitis), constriction of the penis due to scar tissue or foreign material (e.g., malicious placement of string or rubber band), as well as anatomical issues (os penis fracture) or muscular issues such as inefficiency of preputial musculature.
- Paraphimosis may be idiopathic.
- Rarely, paraphimosis may be congenital, due to an abnormally large preputial opening, congenital preputial shortening, or paralysis of retractor penis muscle.

Systems Affected

- Renal/Urologic
- Reproductive
- Skin/Exocrine



CLINICAL FEATURES

- Dogs with paraphimosis of short duration may not have any signs other than the dog's licking of an exteriorized penis. After some hours of exposure, ischemic necrosis and urethral obstruction can develop.



DIFFERENTIAL DIAGNOSIS

- Priapism



THERAPEUTICS

- Paraphimosis requires immediate treatment. After 24 hours, the tissue damage and urethral obstruction may require penile amputation. If urethral patency is in question, place an indwelling urinary catheter. Replacement of the penis in normal position is the goal.
- Anesthesia may be necessary to perform the necessary manipulation to correct the problem.
- Cooled hyperosmotic agents such as dextrose 50%, concentrated sugar solution, concentrated magnesium sulfate solution (Epsom salts), or concentrated saline solution are used to reduce edema and shrink the penis.
- Cold packs may help reduce inflammation and swelling of the penis.

- Penis should be cleaned prior to replacement.
- Lubricants such as K-Y jelly may aid in the return of the penis to the sheath.
- Hair rings or foreign materials should be removed.
- Surgical release of the paraphimotic ring may be required.
- An abdominal compression bandage and indwelling urinary catheter to maintain the penis within the prepuce may also reduce localized edema.

Surgical Considerations

- Surgical release of the prepuce by making a small incision in the preputial orifice may be required to replace the engorged penis back into the prepuce. The preputial incision can be closed in two layers like any other laceration or incision.
- A purse-string suture around the preputial orifice may be considered to help prevent recurrence of paraphimosis until the penile swelling resolves. Use care to avoid overtightening of the purse-string suture, to allow normal urination and instillation of antibiotic ointment into the prepuce.
- Severe cases that result in penile and urethral necrosis may require penile amputation and prepubic urethrostomy.



COMMENTS

Client Education

- Owners should be instructed to prevent dog from licking its penis and to avoid activities that may result in excitement and penile erection.
- Owners should be instructed to keep hair out of the preputial orifice to prevent hair rings from occurring.

Suggested Reading

Feldman, EC, and Nelson, RW. *Canine and Feline Endocrinology and Reproduction*. Philadelphia: WB Saunders, 1987.

Linde-Forsberg, C, and Eneroth, A. Parturition. In: Simpson, GM, Ed. *Manual of Small Animal Reproduction and Neonatology*, pp. 127–142. Cheltenham: British Small Animal Veterinary Association, 1998.

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Acknowledgment to original authors in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Carlos Pinto and Rolf Larsen

Pericardial Effusion



DEFINITION/OVERVIEW

- Pericardial effusion is defined as the accumulation of fluid within the pericardial sac.



ETIOLOGY/PATHOPHYSIOLOGY

- Pericardial effusion is a relatively common reason for dogs to present on an emergency basis.
- Pericardial effusion is much more common in dogs than cats.
- Similar to fluid accumulations in other spaces in the body, pericardial effusion occurs due to one or a combination of the following factors:
 - Increased vascular permeability (e.g., hemorrhage)
 - Decreased capillary oncotic pressure (e.g., severe hypoalbuminemia)
 - Increased capillary hydrostatic pressure (e.g., right-sided heart failure)
 - Decreased lymphatic drainage (e.g., neoplasia)
- Common etiology of pericardial effusion
 - Dogs
 - Neoplasia
 - Hemangiosarcoma
 - Heart base tumor
 - Aortic body tumor (chemodectoma)
 - Ectopic malignant thyroid or parathyroid tissue
 - Mesothelioma
 - Lymphoma
 - Any metastatic neoplasia (e.g., carcinoma)
 - Idiopathic pericardial effusion
 - Anticoagulant rodenticide intoxication
 - Trauma
 - Infection (hematogenous vs. direct seeding due to foreign object)
 - Fungal
 - Bacterial
 - Protozoal

- Cardiac conditions
 - Left atrial rupture due to chronic mitral regurgitation and left atrial dilation
 - Congestive heart failure
 - PPDH
- Inflammatory conditions
 - Pancreatitis
 - Renal failure
 - Immune-mediated diseases
- Hypoalbuminemia
- Cats
 - Cardiac conditions
 - CHF is the most common cause of pericardial effusion in the cat.
 - PPDH
 - Pericardial cyst
 - Neoplasia
 - Lymphoma
 - Metastatic neoplasia
 - Infectious disease
 - FIP
 - Hypoalbuminemia
- Pericardial effusion should be differentiated from cardiac tamponade.
 - Low volume pericardial effusion such as may occur with hypoalbuminemia or various systemic inflammatory disorders may not cause any clinical signs.
 - Cardiac tamponade refers to the condition in which pericardial effusion results in progressively increasing intrapericardial pressure that impairs diastolic filling and manifests with signs of cardiovascular compromise including both forward failure (shock) and right-sided CHF. Cardiac tamponade is more common in dogs than cats.

Systems Affected

Cardiovascular

- Increased intrapericardial pressures result in decreased diastolic filling.
- Decreased diastolic filling results in decreased stroke volume.
- Decreased stroke volume results in decreased cardiac output.
- Decreased cardiac output results in decreased oxygen delivery to the tissues (shock).
- Signs of right-sided CHF predominate.
- Cardiovascular manifestations of pericardial effusion are important to the diagnosis of the condition based on physical examination.

Nervous

- Decreased mentation (i.e., obtunded, stupor, or coma) may occur secondary to hypotension and decreased oxygen delivery to the brain.

Gastrointestinal

- Gastrointestinal manifestations of pericardial effusion are likely a result of decreased gastrointestinal blood flow and may include vomiting or diarrhea.

Renal/Urologic

- Decreased renal blood flow may result in prerenal azotemia.



SIGNALMENT/HISTORY

- The underlying etiology of pericardial effusion may determine the patient population most commonly affected.
 - Adult to geriatric golden retrievers and German shepherds commonly develop pericardial effusion secondary to hemangiosarcoma involving the right atrium and surrounding tissues.
 - Brachycephalic breeds and retriever breeds may have a higher incidence of heart base tumors.
 - Young dogs may be more prone to developing pericardial effusion secondary to anticoagulant rodenticide ingestion.

Risk Factors/Causes

- Rodenticide ingestion
- History of neoplasia, especially hemangiosarcoma, lymphoma, carcinoma, and mesothelioma at local or distant sites.
- Historical cardiac disease
- Known septic focus
- Conditions that cause systemic inflammation or hypoalbuminemia
- Recent cardiac surgery
- Recent trauma

Historical Findings

- Presenting complaints
 - Collapse
 - Lethargy
 - Anorexia
 - Vomiting
 - Abdominal distention
- Duration of signs
 - Dogs and cats with pericardial effusion may have peracute history (minutes to hours) or a chronic history (days to weeks).



CLINICAL FEATURES

General

- Pericardial effusion resulting in cardiac tamponade should be highly suspected based on thorough physical examination. Echocardiography is critical to definitive diagnosis.

Physical Examination

Cardiovascular System

- Pale mucous membranes
- Prolonged capillary refill time
- Tachycardia
- Poor pulse quality
- Auscultation of the heart reveals decreased heart sounds. Lung auscultation is generally normal.
- Jugular venous distention (with or without pulsations) This finding helps differentiate pericardial effusion from hemoperitoneum.
 - Compression of the cranial abdomen may exacerbate jugular venous distention (with or without pulsation). This is termed the hepatojugular reflex.
- Pulsus paradoxus is a normal phenomenon in which pulse quality varies with the phase of the respiratory cycle. Pericardial effusion exacerbates pulsus paradoxus.
- Arrhythmia may be noted while concurrently palpating the pulse and ausculting the heart.
- Abdominal distention results from right-sided CHF. High intrapericardial pressures result in high caudal caval pressures, which are transmitted to the hepatic venous system resulting in abdominal effusion.

Respiratory System

- Increased respiratory rate and effort may occur.
- Lung sounds are usually normal for the degree of respiratory effort. Lung sounds may be decreased if concurrent pleural effusion is present.

Central Nervous System

- Varying degrees of altered mentation may be noted due to a lack of oxygen delivery to the brain. These may include obtundation, stupor, or coma.



DIFFERENTIAL DIAGNOSIS

- Hypovolemia due to hemoperitoneum
 - Hypovolemia due to blood loss (into any potential space) may result in many identical cardiovascular, respiratory, and CNS signs.

- Differentiating findings
 - In hypovolemia, the jugular vein is generally small or flat.
 - Heart sounds are usually normal in hypovolemia although they may be quiet.
 - Pulsus paradoxus is not common in hypovolemia.
- Abdominocentesis will help rule out hemoperitoneum.
- CHF due to other cardiac diseases
 - Other cardiac disease causing CHF and cardiogenic shock may result in similar cardiovascular signs of pericardial effusion.
 - Right-sided disease
 - Dilated cardiomyopathy (dogs and cats)
 - Heartworm disease (caval syndrome)
 - Tricuspid regurgitation
 - Congenital cardiac anomalies
 - Left-sided disease
 - Dilated cardiomyopathy (dogs and cats)
 - Hypertrophic cardiomyopathy (cats)
 - Mitral regurgitation (dogs)
 - Congenital cardiac anomalies
- Differentiating findings
 - Animals with CHF generally have very audible heart sounds.
 - Animals with CHF generally have heart murmurs or other auscultable abnormalities (gallop rhythm in cats).
 - Animals with CHF (especially dilated cardiomyopathy in dogs) often present with evidence of atrial fibrillation and other arrhythmias.
 - Animals in left-sided CHF often have pulmonary edema with increased lung sounds and more pronounced respiratory distress.
- Echocardiography will definitively differentiate between CHF and pericardial effusion.



DIAGNOSTICS

Hemostasis Assessment

- Rodenticide intoxication is a cause of pericardial effusion.
- Hemostasis testing should be performed prior to pericardiocentesis
- Point-of-care coagulation analyzers are available to measure PT and aPTT.
- ACT is an alternative to aPTT and may aid in the identification of severe intrinsic/common cascade abnormalities without the need for a coagulation analyzer.
- Blood smear can be rapidly performed to identify the presence of severe thrombocytopenia.

Echocardiography/Ultrasound

- Point-of-care ultrasound capabilities are critical to the management of dogs and cats in the emergency setting.

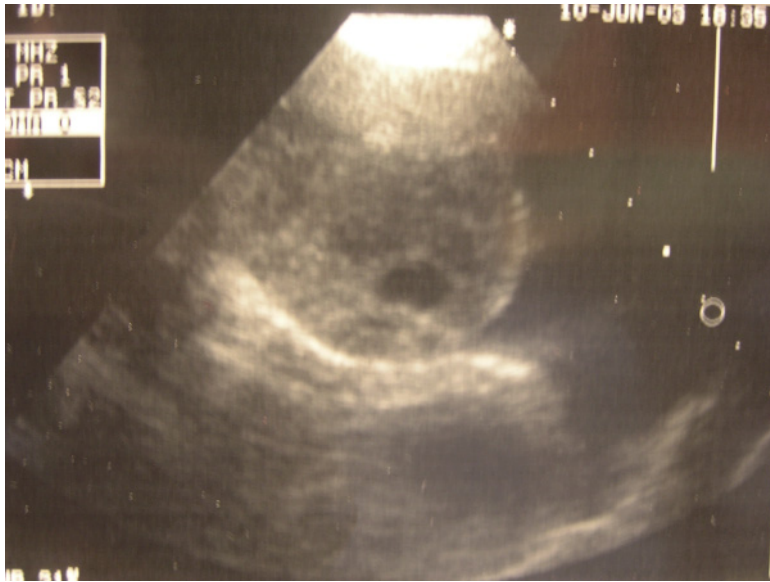


■ **Figure 72.1** Pericardial effusion in a cat. Note the hyperechoic pericardium and hypoechoic fluid in between the pericardium and the heart.

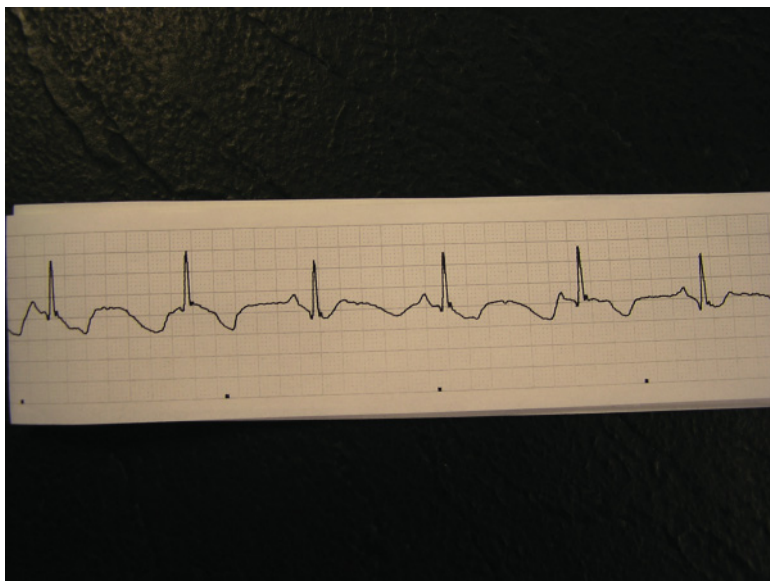
- Allows for rapid, definitive diagnosis of pericardial effusion
- May aid in identification of an underlying cause (e.g., neoplasia)
- Minimally invasive
- Dogs and cats are best imaged from the right cardiac notch
- Findings
 - Hypoechoic fluid between the epicardium and the echodense pericardium. (Figure 72.1)
 - Inward deviation/compression of the right atrium
 - With or without presence of a mass (Figure 72.2)
 - Due to stretch of the pericardium over time, it should be noted that small volume pericardial effusion may be associated with severe clinical signs if accumulation occurs acutely. Conversely, if accumulation occurs slowly, larger volume accumulations may result in only mild clinical signs.

Electrocardiography

- Electrocardiography provides a rapid diagnostic tool that will aid in the identification of pericardial effusion.
- Findings in Lead II supportive of pericardial effusion (*indicates critical finding)
 - Decreased QRS complex amplitude (<1 mV)*
 - Electrical alternans resulting from movement of the heart within the pericardial sac to and from the positive pole of lead IIF (Figure 72.3)
 - Tachycardia



■ **Figure 72.2** Ultrasound image of pericardial effusion and a heart base tumor in a dog.



■ **Figure 72.3** Electrocardiogram strip of electrical alternans in a dog with pericardial effusion. Note the higher amplitude complexes followed by lower amplitude complexes as the heart swings in the fluid within the pericardial sac. Electrical alternans is not always seen in all cases of pericardial effusion.

- Arrhythmias
- ST segment changes (elevation or depression)

Abdominocentesis

- Although not diagnostic for pericardial effusion, abdominal effusion that accumulates in patients with pericardial effusion is frequently a modified transudate in character. Abdominocentesis can rule out hemoperitoneum, a condition that mimics some of the clinical findings of patients with pericardial effusion.

Blood Gas Analysis

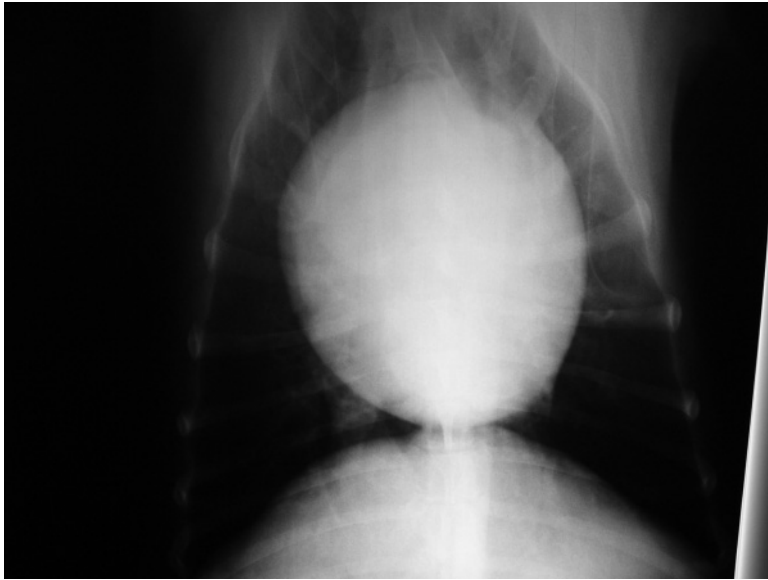
- Although not diagnostic for pericardial effusion, blood gas analysis may reveal metabolic (lactic) acidosis associated with decreased oxygen delivery to the tissues due to cardiogenic shock.

Thoracic Radiography

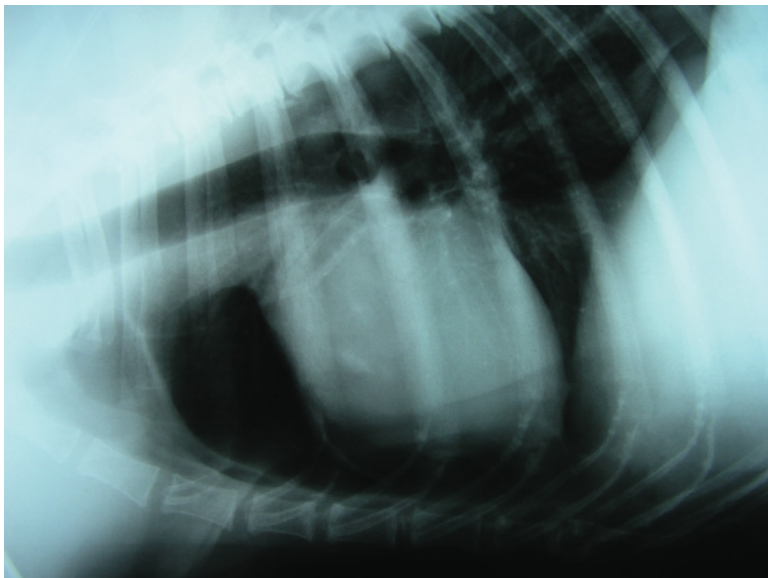
- Thoracic radiography should be avoided if possible in favor of echocardiography and electrocardiography because it may require significant patient manipulation and stress.
- If necessary, the patient should be stabilized prior to performing thoracic radiography.
- Views
 - Dorsoventral
 - Lateral
- Findings
 - Enlarged, globoid cardiac silhouette (Figure 72.4)
 - Acute pericardial effusion may demonstrate a normal cardiac silhouette.
 - Sharp border of the cardiac silhouette is due to its fixed location in contrast to a moving pericardium/epicardium in a dog that does not have pericardial effusion.
 - Enlargement of the caudal vena cava
 - Low volume pleural effusion may be present.
 - Note that the cardiac silhouette may appear normal in cases of acute tamponade, when the pericardial sac has not had time to stretch. In such cases, the caudal vena cava still appears large (Figure 72.5).
 - Pulmonary changes
 - Pulmonary edema is uncommon in dogs with pericardial effusion.
 - Pulmonary edema is common in dogs and cats with left-sided CHF.
 - Pulmonary metastatic disease may be noted in dogs with hemangiosarcoma.

Pericardial Fluid Analysis

- Pericardial fluid is retrieved with pericardiocentesis.
- Analysis should include:



■ **Figure 72.4** Globoid cardiac silhouette in a dog with pericardial effusion.



■ **Figure 72.5** Pericardial effusion in a dog whose pericardial sac has not had time to stretch, resulting in a normal appearing cardiac silhouette with an enlarged caudal vena cava.



■ **Figure 72.6** Evaluate the fluid carefully for clots because clots can form with inadvertent intracardiac punctures.

- Assessment for clotting. Pericardial fluid that clots likely was retrieved from one of the cardiac chambers, or can be associated with ongoing hemorrhage (Figure 72.6)
- Cytologic analysis may aid in the identification of the underlying cause, especially in bacterial and fungal pericarditis.
 - Some types of neoplasia may also exfoliate cells into the pericardial fluid.
 - Mesothelioma; interpretive caution should be exercised as reactive mesothelial cells have many characteristics of malignancy.
 - Lymphoma
 - Carcinoma
 - Hemangiosarcoma and heart-base tumors are rarely diagnosed cytologically.
- Aerobic, anaerobic, and fungal cultures should be performed if bacterial or fungal etiology is suspected cytologically.
- Acid-base analysis is not a useful predictor of the cause of pericardial effusion.

Cross-Sectional Imaging

- Only considered if traditional diagnostic testing is nondiagnostic and the patient has been stabilized with pericardiocentesis.
- CT or MRI gated to the cardiac cycle may provide additional information as to the underlying cause for the pericardial effusion, especially in cases of neoplasia.

Pathological Findings

Gross

- Distention of the pericardium with fluid
- Gross changes in dogs with pericardial effusion will be a reflection of the underlying disease process.

Histopathologic

- Histopathologic changes in dogs with pericardial effusion will be a reflection of the underlying disease process.



THERAPEUTICS

- The objective of treatment for dogs and cats with pericardial effusion is the establishment or maintenance of hemodynamic stability.
- Dogs and cats with cardiac tamponade require emergent evacuation of their pericardial effusion in order to achieve hemodynamic stability.
- Although pericardiocentesis for diagnostic purposes may be indicated, patients with low-volume pericardial effusion and few clinical signs may not warrant therapeutic pericardiocentesis.

Pericardiocentesis

- Oxygen therapy maximizes oxygen saturation.
- Achieve peripheral intravenous access for the delivery of medications including sedation if needed.
- There is little place for fluid therapy, diuretics, or vasodilators in the acute management of pericardial effusion.
- If, based on assessment of coagulation status, severe coagulopathy is considered a likely cause of pericardial effusion, correcting coagulation abnormalities with FFP (15–20 mL/kg) should be attempted prior to pericardiocentesis. FFP can be delivered rapidly (<1 hour) if necessary. However, if the pericardial effusion is associated with lactic acidosis or thought to be immediately life threatening, pericardiocentesis should be performed as plasma is being delivered.
- ECG should be monitored throughout the procedure.
- Pericardiocentesis
 - Light sedation should be considered to help alleviate stress and anxiety and to decrease the likelihood of patient motion during pericardiocentesis.
 - Midazolam 0.1 to 0.2 mg/kg IV
 - Opioid (choose one)
 - Butorphanol 0.1 to 0.2 mg/kg
 - Fentanyl 1 to 3 µg/kg IV
 - Hydromorphone 0.05 mg/kg IV

- Equipment
 - Fenestrated drape
 - Pericardiocentesis device
 - 14- to 16-gauge 5.25-inch over-the-needle catheter (large dogs)
 - 18-gauge 1- to 2-inch over-the-needle catheter (small dogs and cats)
 - Intravenous extension tubing: three-way stopcock, 20- to 60-mL syringe interconnected
 - 3-mL syringe filled to 1.5 mL with sterile saline
- Positioning
 - Sternal recumbency
 - Landmarks for pericardiocentesis
 - Right hemothorax
 - Ultrasound can be utilized to identify the optimal rib space for pericardiocentesis.
 - Alternatively, the apex beat (if palpable) is a reasonable target.
 - Alternatively, the elbow can be pulled back to where it touches the chest (third to fifth rib space).
 - Preparation
 - Clip and aseptically prepare the right side of the thorax centering on the third to sixth rib spaces in the ventral half of the chest.
 - Apply a fenestrated drape.
 - Sterile technique should be utilized at all times.
- Technique
 - Apply 3-mL saline syringe to end of pericardiocentesis catheter and flush.
 - Advance pericardiocentesis catheter through the skin in the predetermined location just cranial to the edge of a rib (Figure 72.7).
 - The “closed” system (syringe attached to over-the-needle catheter) prevents pneumothorax.
 - Advance pericardiocentesis catheter in 2- to 4-mm increments until a “flash” of fluid is seen in the syringe. Many effusions are hemorrhagic.
 - Advance pericardiocentesis catheter 2 mm.
 - Advance catheter over the stylet and into the pericardium.
 - Connect intravenous extension tubing: three-way stopcock, 20- to 60-mL syringe to catheter and evacuate pericardial space.
 - Collect initial sample to assess for clotting. If the sample clots, remove the catheter and start over.
 - Collect additional samples as indicated.
 - On occasion, the catheter will become occluded on the epicardium or inner pericardium. Rotation of the catheter and repositioning may be effective.
 - Create a 2- to 3-mm sidehole in the catheter approximately 7 to 10 mm from its tip prior to pericardiocentesis to minimize the likelihood of this problem. Caution should be taken not to destabilize the structural integrity of the catheter by creating too large of a defect.



■ **Figure 72.7** Insert the long catheter in between rib spaces as described in the text, and watch for a flash of blood in the hub of the needle. Note that this technique should be performed in a sterile manner. This photo demonstrates location and patient anatomy for instruction purposes.

Additional Treatment Considerations

- If anticoagulant rodenticide is considered the cause of the pericardial effusion, initiation of vitamin K1 therapy is indicated after FFP administration and pericardiocentesis.

Precautions/Interactions

- Pericardiocentesis is not without risk. Injury to the chest wall (i.e., intercostal vascular injury), lung (i.e., pneumothorax), and heart (i.e., arrhythmias, chamber puncture, or coronary artery laceration) are all possibilities although very rare.
- Ventricular arrhythmias may be noted when the catheter contacts the epicardium. If this occurs, the position of the catheter should be modified.

Diet

- The patient should feel much better soon after pericardiocentesis. Feeding should be considered after hemodynamic stability is achieved.

Activity

- Activity should only be restricted if ongoing bleeding is considered a significant possibility such as in animals with anticoagulant rodenticide intoxication.

Surgical Considerations

- There is a specific place for the surgical management of pericardial effusion in a variety of conditions.
 - Idiopathic pericardial effusion is generally initially managed through pericardiocentesis. If the effusion reaccumulates, then open surgical or thoracoscopic evaluation of the heart and thorax should be performed with subtotal pericardectomy or pericardial window to eliminate recurrence respectively. As is routine, biopsies should be acquired to rule out the possibility of neoplasia (especially mesothelioma).
 - Cardiac or pericardial neoplasia is initially managed through pericardiocentesis. Tumors of the right atrial appendage can often be removed quite easily. There is significant debate as to the value of subtotal pericardectomy or pericardial window in dogs with masses of the heart. Pericardectomy in dogs with masses that have not previously demonstrated severe, acute, or large volume hemorrhage is recommended. Heart-base tumors (i.e., aortic body tumors) commonly behave this way. Biopsies should be acquired for definitive diagnosis if possible. Hemorrhage from biopsy sites may be severe.
 - Bacterial or fungal pericarditis may occur due to hematogenous spread or direct implantation due to penetrating injury or migrating foreign body. Pericardiocentesis should be performed to achieve initial stability. Pericardectomy and establishment of ongoing pleural drainage with thoracostomy tubes coupled with aggressive appropriate antimicrobial therapy are then indicated for definitive treatment.
 - Surgical repair of left atrial rupture secondary to chronic mitral valve insufficiency is possible.
 - Pericardectomy plays a role in the management of restrictive pericarditis.
 - Peritoneopericardial diaphragmatic hernia is managed by replacing abdominal contents back into the abdominal space and repairing the defect in the diaphragm.



COMMENTS

Client Education

- Client education will be specific to the underlying cause of pericardial effusion. Clients should monitor for recurrence of clinical signs which could signify reaccumulation of pericardial fluid.

Patient Monitoring

- Pericardiocentesis is considered one of the most rewarding clinical procedures because it results in very rapid improvement in clinical signs. Postprocedural monitoring may include any (or all) of the following:

- Intermittent physical examination will allow the practitioner to monitor for abnormalities associated with pericardial effusion.
- ECG will demonstrate heart rate and the presence of arrhythmias. If pericardial effusion reaccumulates, the heart rate will rise.
- Intermittent point-of-care assessment for the recurrence of pericardial effusion can be performed via ultrasound or echocardiogram.
- Central venous pressure will rise above the baseline measurements when pericardial effusion accumulates.

Prevention/Avoidance

- If a predisposing condition such as anticoagulant rodenticide intoxication is diagnosed as the cause of pericardial effusion, eliminating the toxin from the environment is critical to preventing a second bout of intoxication.

Possible Complications

- The most common long-term complication of pericardial effusion is recurrence. Recurrence rates will be dependent on the underlying disease process and the treatment rendered. For example, idiopathic pericardial effusion and pericardial effusion secondary to neoplasia are likely to recur.

Expected Course and Prognosis

- As a general rule, pericardiocentesis results in immediate relief of symptoms of pericardial effusion.
- Prognosis over time will be dependent on the underlying cause of the pericardial effusion.
 - Neoplasia: Prognosis in dogs and cats with neoplasia is dependent on the type of tumor and the treatment rendered. For example, dogs with hemangiosarcoma that undergo surgical intervention for tumor resection and treatment with chemotherapy have a median survival time of approximately 5 months. Dogs with aortic body tumors treated with pericardectomy had median survival time of approximately 2 years in one series.
 - Idiopathic: Dogs with idiopathic pericardial effusion generally respond favorably to pericardiocentesis. If recurrence occurs, pericardectomy is recommended. A good prognosis is generally given.
 - Cats: The most common cause of pericardial effusion in the cat is CHF. Prognosis in cats with pericardial effusion is generally dependent on the prognosis for the underlying disease process.

Abbreviations

- ACT: activated clotting time
- aPTT: activated partial thromboplastin time
- CHF: congestive heart failure

- CNS: central nervous system
- CT: computed tomography
- ECG: electrocardiogram
- FFP: fresh frozen plasma
- FIP: feline infectious peritonitis
- IV: intravenously
- MRI: magnetic resonance imaging
- PPDH: peritoneo-pericardial diaphragmatic hernia
- PT: prothrombin time

Suggested Reading

- Ehrhart, N, Ehrhart, EJ, Willis, J, et al. Analysis of factors affecting survival in dogs with aortic body tumors. *Vet Surg* 2002;31:44–48.
- Hall, DJ, Shofer, F, Meier, CK, and Sleeper, MM. Pericardial effusion in cats: a retrospective study of clinical findings and outcome in 146 cats. *J Vet Intern Med* 2007;21:1002–1007.
- Shaw, SP, and Rush, JE. Canine pericardial effusion: diagnosis, treatment, and prognosis. *Comp Contin Educ Vet* 2007;29:405–411.
- Shaw, SP, and Rush, JE. Canine pericardial effusion: pathophysiology and cause. *Comp Contin Educ Vet* 2007;29:400–403.
- Weisse, C, Soares, N, Beal, MW, et al. Survival times in dogs with right atrial hemangiosarcoma treated by means of surgical resection with or without adjuvant chemotherapy: 23 cases (1986–2000). *J Am Vet Med Assoc* 2005;226:575–579.

Author: Matthew W. Beal

Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: John E. Rush

Peritonitis



DEFINITION/OVERVIEW

- Peritonitis is an inflammatory process that results from contamination of the abdominal cavity by either microorganisms or inflammatory chemicals.
- Peritonitis may be generalized and involve the entire abdominal cavity or localized to a portion of the abdomen.



ETIOLOGY/PATHOPHYSIOLOGY

- Primary peritonitis occurs uncommonly and is direct infection of the abdominal cavity through hematogenous spread. An example is feline infectious peritonitis.
- Secondary peritonitis is more common and occurs secondary to bacterial or chemical contamination of the abdomen. Examples are disruption of the abdominal cavity due to a penetrating abdominal wound or rupture of a hollow viscus or abdominal abscess.
- Peritoneal injury leads to release of vasoactive substances and increased capillary permeability. Fluid, electrolytes, protein, and red blood cells are lost into the abdominal cavity and result in a decreased circulatory volume.
- White blood cells enter the abdominal cavity and begin to destroy bacteria. Proteases and endotoxins are released that contribute to the inflammatory response.
- Sympathetic stimulation causes gastrointestinal stasis. Ileus and peritoneal stimulation lead to vomiting that contributes to fluid losses.
- The decreased circulatory volume leads to hypovolemic shock. Absorption of bacterial and tissue toxins causes septic shock that contributes further to hypotension and tissue hypoxia.
- Eventually organ failure and death will result if left untreated.

Systems Affected

Cardiovascular

- Hypovolemia causes decreased cardiac output. Sympathetic nervous system activation causes increased cardiac contractility and vasoconstriction. Decreased tissue

perfusion results in myocardial ischemia. Myocardial ischemia and electrolyte imbalances may trigger cardiac dysrhythmias that in turn further decrease cardiac output.

Gastrointestinal

- Sympathetic stimulation inhibits peristalsis. Ileus and peritoneal inflammation lead to vomiting, which contributes to fluid losses.

Hemic/Lymphatic/Immune

- Irritation of the peritoneal lining stimulates the inflammatory cascade. White blood cells, red blood cells, proteins, electrolytes, and fluid enter the peritoneal space. White blood cells destroy bacteria and cause the release of proteases and endotoxins. The coagulation cascade is activated.

Hepatobiliary

- Decreased perfusion and bacterial endotoxin cause hepatocellular necrosis and liver failure. Hypoglycemia may occur due to bacterial consumption of glucose, depleted hepatic glycogen stores, and impaired gluconeogenesis.

Nervous

- Decreased blood pressure results in activation of the sympathetic nervous system.

Renal/Urologic

- Decreased cardiac output and compensatory vasoconstriction can cause renal ischemia that may progress to renal failure.

Respiratory

- Respiratory rate increases in response to tissue hypoxia.



SIGNALMENT/HISTORY

Risk Factors/Causes

- Abdominal trauma, recent gastrointestinal surgery, source of infection within the abdomen: gall bladder necrosis, hepatic abscess, prostatic abscess, pyometra, pancreatic abscess, gastrointestinal obstruction, or perforation

Historical Findings

- Lethargy
- Vomiting, anorexia
- Abdominal pain, abnormal posturing such as hunched posture or “prayer position”

- Abdominal distension
- Possible history of recent trauma or gastrointestinal surgery



CLINICAL FEATURES

- Lethargy
- Fever or hypothermia
- Dehydration
- Abdominal pain, possible abdominal fluid wave
- Pale or injected mucous membranes
- Prolonged capillary refill time
- Tachycardia with rapid, weak peripheral pulses
- Tachypnea



DIFFERENTIAL DIAGNOSIS

- Gastrointestinal obstruction without peritonitis
- Pancreatitis
- Hemoabdomen
- Sepsis without peritonitis
- Hypovolemic shock without peritonitis
- Splenic torsion
- Mesenteric torsion

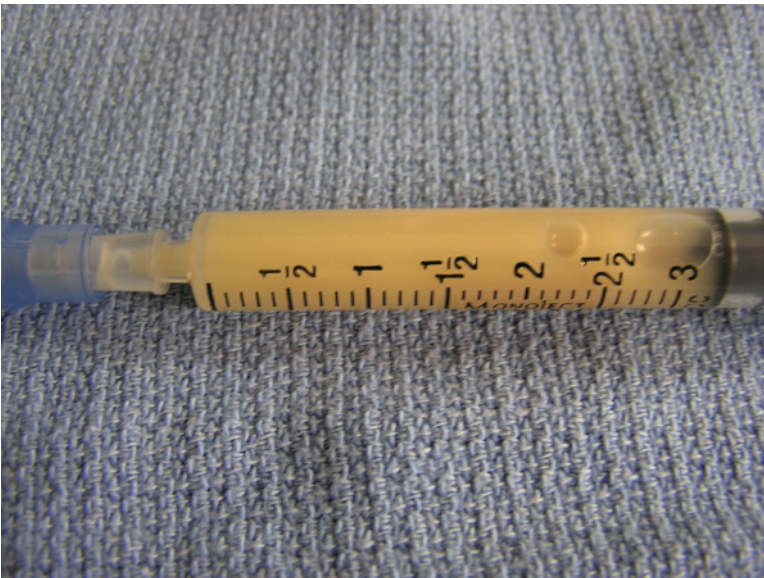


DIAGNOSTICS

- Abdominocentesis: Diagnostic test most likely to provide rapid, definitive diagnosis of peritonitis. May be performed with ultrasound guidance or using aseptic four quadrant technique by aseptically inserting a 20-gauge needle or catheter into the abdomen (patient standing or in lateral recumbency) (Figure 73.1). If fluid does not flow through the needle spontaneously, gently aspirate using a 3-ml syringe.
- With peritonitis the fluid is typically turbid or cloudy (Figure 73.2).
- Diagnostic peritoneal lavage: If abdominocentesis is negative but peritonitis is suspected, infuse 22 ml/kg warm isotonic fluid into the abdominal cavity. Roll patient from side to side and aspirate fluid with abdominocentesis for cytology.
- Abdominal fluid cytology: WBC greater than 10,000 cells/ μ l on abdominocentesis fluid and greater than 1,000 cells/ μ l on DPL fluid is indicative of peritonitis. Presence of toxic neutrophils, plant material, and intracellular bacteria confirms peritonitis. Bile pigment may be visualized on cytology with biliary tract rupture.
- Abdominal fluid culture and sensitivity: May help to guide antibiotic therapy.



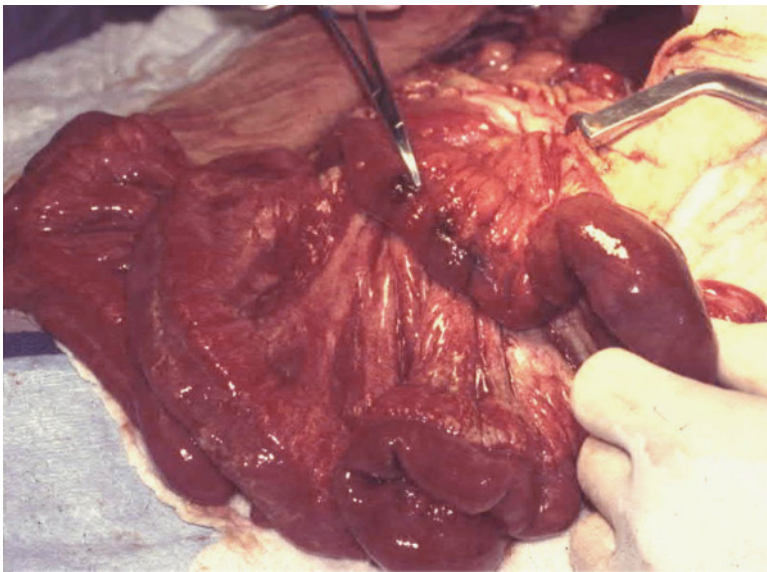
■ **Figure 73.1** Abdominocentesis and fluid cytology can provide a rapid, definitive diagnosis of peritonitis. A 20- or 22-gauge 1-inch needle is inserted into the abdomen and fluid is allowed to drip out of the open end of the needle and is collected for analysis.



■ **Figure 73.2** Purulent abdominal fluid from a dog with septic peritonitis secondary to a perforated jejunum and gastrointestinal foreign body.

- Abdominal fluid creatinine: Exceeds serum creatinine with uroabdomen
- Abdominal fluid bilirubin: Exceeds serum bilirubin with biliary tract rupture.
- Ultrasound: Free fluid and peritoneal inflammation can be visualized. Source of peritonitis may be identified (i.e., gastrointestinal foreign body, pyometra, hepatic or prostatic abscess, etc.).

- Abdominal radiographs: Loss of abdominal detail indicates the presence of abdominal fluid but not the type of fluid. Free gas may be noted within the abdominal cavity with rupture of hollow viscus or gas-forming bacteria. Generalized ileus may be noted.
- Contrast studies: Contraindicated with suspected gastrointestinal tract rupture as barium and iodinated contrast materials can increase severity of peritonitis. Water soluble iodinated contrast may be used to evaluate the integrity of the urinary tract.
- CBC: Leukopenia or leukocytosis with left shift. Thrombocytopenia may be noted due to platelet consumption and DIC. Hemoconcentration may be noted due to dehydration.
- Chemistry panel: Renal values may be increased due to dehydration or renal failure. Hepatic enzymes may be increased due to decreased hepatic perfusion and ischemia. Blood glucose may initially be increased due to sympathetic stimulation but then becomes decreased due to hepatic dysfunction and increased metabolic rate. Albumin is decreased due to liver failure, malnutrition, fluid therapy, fluid sequestration in the abdomen, and increased capillary permeability. Electrolyte imbalances are common.
- Blood gases: Metabolic acidosis
- Lactate levels: Increased due to tissue hypoxia
- Abdominal fluid lactate >2.0 mmol/liter greater than peripheral blood strongly suspicious for septic peritonitis
- Abdominal fluid glucose less than 20 mg/dL compared with peripheral blood strongly suspicious for septic peritonitis
- Coagulation panel: Coagulation times may be prolonged due to DIC.



■ **Figure 73.3** This patient has a generalized peritonitis secondary to a linear foreign body that has perforated the intestine along the mesenteric border at multiple sites. Note the hemorrhagic appearance of the intestines and the petechial hemorrhages throughout the mesentery.

- Note: Free gas may be present within the abdomen for up to 5 weeks following abdominal surgery and increased white blood cells (as high as 10,000 cells/ μ l) without bacteria can be noted on abdominocentesis for up to 3 days following abdominal surgery so these factors should be considered in postoperative patients.

Pathologic Findings

- Free abdominal fluid which may contain plant material or bile
- Inflammation of the peritoneal lining and serosal surface of the abdominal viscera
- Omental and fibrin adhesions may be present (Figure 73.3).
- Other pathology varies depending on the source of the contamination.



THERAPEUTICS

- Supportive medical therapy
- Intravenous fluid therapy with crystalloids and colloids. Colloids are an important part of fluid therapy due to increased capillary permeability and tendency for protein loss into the interstitial space.
- Correct electrolyte imbalances
- Dextrose supplementation as indicated by blood glucose
- Broad-spectrum antibiotics
- Analgesics
- Inotropic support as needed for hypotension and to increase renal perfusion once volume replacement is completed
- Nutritional support via naso-esophageal, esophageal, gastrostomy, jejunostomy, or other feeding tube
- Blood products as needed to treat coagulation disorders, anemia, or hypoalbuminemia
- Anti-emetics and pro-motility agents to control vomiting
- Gastroprotectants
- Surgical correction of the underlying problem to prevent further contamination
- Resection and anastomosis of intestines with intestinal perforation, cholecystectomy for gall bladder rupture, urinary bladder repair, etc.
- Copious lavage of the abdomen with warm, sterile saline (200–300 ml/kg)
- All foreign material, necrotic tissue, and blood clots should be removed from the abdomen at the time of exploratory surgery.
- Placement of closed suction drain or open peritoneal drainage should be considered to allow continued abdominal drainage (Figure 73.4).

Drug(s) of Choice

- Crystalloid fluids: Balanced electrolyte solution such as Normosol R, lactated Ringer's solution, or Plasmalyte, administer shock bolus of up to 90 ml/kg (dog) and 45 ml/kg (cat) initially then continue fluids as needed to maintain perfusion.



■ **Figure 73.4** Closed suction drainage can effectively be used in the treatment of generalized peritonitis. This is a Jackson-Pratt drain. The multiply fenestrated drain is placed within the abdominal cavity and the tubing is tunneled through the abdominal wall and connected to the bulb portion of the drain. Squeezing the air from the bulb portion of the drain creates negative pressure and pulls fluid from the abdomen into the bulb ("grenade").

- **Colloids:** Hetastarch 15 to 20ml/kg per day, dextran 70 14 to 20ml/kg per day, plasma 10 to 30ml/kg or concentrated (25%) human serum albumin (5ml/kg IV slowly over 4–8 hours; watch for signs of a reaction) particularly if patient has coagulopathy or is hypoalbuminemic.
- **Antibiotics:** Combination of ampicillin (22mg/kg IV every 6–8 hours) or ampicillin/sulbactam (50mg/kg IV every 6–8 hours) with enrofloxacin (5–10mg/kg IV every 24 hours). An alternative is to use cefoxitin (30mg/kg IV every 8 hours). Base continued antibiotic therapy on culture and sensitivity results.
- **Analgesics:** Fentanyl CRI 3 to 7µg/kg per hour or morphine CRI 0.1 to 0.5mg/kg per hour

Precautions/Interactions

- Corticosteroids have been used to decrease inflammation and adhesion formation and for positive cardiac effects; however corticosteroids can also increase potential

for gastrointestinal ulceration and cause immunosuppression so their use is controversial.

- Nonsteroidal anti-inflammatory medications have also been advocated for their anti-inflammatory effects but also increase the risk of gastrointestinal ulceration and renal toxicity so their use is not recommended.

Diet

- Due to ongoing protein losses and increased metabolic rate, these patients require aggressive nutritional support.
- A jejunostomy or other feeding tube should be placed at surgery to allow for enteral nutrition.
- Parenteral nutrition can also be used to provide support but can be more complicated and does not help to maintain the intestinal mucosa.

Surgical Considerations

- There has been a recent trend toward the use of closed suction drains in the treatment of peritonitis rather than open abdominal drainage. One study showed similar survival rates (70 percent) for patients treated with closed suction drainage compared to a previous study which utilized either open abdominal drainage or primary closure without any type of drainage system. Open abdominal drainage allows for rapid and effective drainage of the abdomen, but there is higher potential for ascending infection and dehiscence and evisceration. Additionally, it tends to be labor intensive and is associated with greater fluid and protein losses and longer hospitalization. There has been concern that closed abdominal drains would seal over with fibrin and omentum and not provide effective drainage; however in the above mentioned study, all drains remained functional until they were removed. There is still risk for ascending infection with the use of closed suction drainage, and there is the potential for the drain to be prematurely removed by the patient.



COMMENTS

Client Education

- The client should be informed of cost and prognosis prior to proceeding with treatment.

Patient Monitoring

- Mentation, body temperature, pulse, respiration every 3 to 6 hours
- Continuous monitoring of vomiting/diarrhea and urine output
- Blood pressure every 3 to 6 hours
- Central venous pressure every 6 hours
- Hematocrit, total protein every 12 hours
- Blood glucose every 6 to 12 hours

- Electrolytes every 12 hours
- Coagulation parameters every 12 to 24 hours
- Abdominal fluid cytology: Evaluate every 24 hours for reduction in white blood cells and presence or absence of bacteria.

Possible Complications

- Anemia
- Hypoproteinemia
- Hypoglycemia
- Hypotension
- Cardiac arrhythmias
- Multiple organ failure
- DIC

Expected Course and Prognosis:

- Prognosis is guarded with patients that require aggressive therapy and monitoring.
- Recent studies indicate survival rates of approximately 70 percent with surgery and aggressive therapy although survival rates in previous studies were significantly lower (52 percent).

Abbreviations

- CBC: complete blood count
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- DPL: diagnostic peritoneal lavage
- IV: intravenously
- WBC: white blood count

Suggested Readings

- Dullish, ML. Peritonitis. In: Bojrab, MJ, ed. *Disease Mechanisms in Small Animal Surgery*, 2nd ed., pp. 109–113. Philadelphia: Lippincott, Williams, & Wilkins, 1993.
- Greenfield, CL. Open peritoneal drainage. In: Harari, J, ed. *Small Animal Surgery Secrets*, pp. 144–148. Philadelphia: Hanley & Belfus, 2001.
- MacPhail, C. Peritonitis. In: Wingfield, WE, ed. *Veterinary Emergency Medicine Secrets*, 2nd ed., pp. 304–309. Philadelphia: Hanley & Belfus, 2001.
- Mueller, MG, Ludwig, LL, and Barton, LJ. Use of closed-suction drains to treat generalized peritonitis in dogs and cats: 40 cases (1997–1999). *J Am Vet Med Assoc* 2001;219(6):789–794.
- Staatz, AJ, Monnet, E, and Seim, HB. Open peritoneal drainage versus primary closure for the treatment of septic peritonitis in dogs and cats: 42 cases (1993–1999). *Vet Surg* 2002;31(2): 174–180.

Author: Teresa Dye

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Sharon Fooshee Grace

Pleural Effusion



DEFINITION/OVERVIEW

- Abnormal accumulation of fluid within the pleural space



PATHOPHYSIOLOGY/ETIOLOGY

- Increased production of fluid or decreased resorption of fluid
- Increased vascular permeability
- Increased hydrostatic pressure of the capillaries or lymphatics
- Decreased intravascular oncotic pressure

Systems Affected

- Respiratory—atelectasis of lungs results in hypoxia and restrictive respiratory pattern
- Cardiovascular—decreased intravascular fluid volume and decreased venous return to the right-sided heart result in decreased cardiac filling, decreased cardiac output, and hypotension



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predilection

- Varies with underlying cause

Mean Age and Range

- Varies with underlying cause

Predominant Sex

- Varies with underlying cause

Historical Findings

- Respiratory difficulty
- Tachypnea
- Orthopnea
- Open-mouth breathing
- Cyanosis
- Exercise intolerance
- Lethargy
- Inappetence
- Cough

Physical Examination Findings

- Respiratory difficulty
- Restrictive, rapid, and shallow respiratory pattern
- Muffled heart and lung sounds
- Dullness on thoracic percussion of ventral lung fields

Risk Factors/Causes

- Increased hydrostatic pressure
 - CHF
 - Overhydration
 - Intrathoracic neoplasia
- Decreased oncotic pressure
 - Hypoalbuminemia (due to protein-losing enteropathy, protein-losing nephropathy, or severe hepatic disease)
- Vascular or lymphatic abnormality
 - Infectious—bacterial, viral, or fungal
 - Neoplasia (e.g., mediastinal lymphosarcoma, thymoma, mesothelioma, primary lung tumor, metastatic disease)
 - Chylothorax (e.g., from lymphangiectasia, idiopathic, CHF, cranial vena cava obstruction, neoplasia, fungal granuloma, heartworm disease, diaphragmatic hernia, lung lobe torsion, trauma)
 - Pancreatitis
 - Diaphragmatic hernia
 - Lung lobe torsion (Figure 74.1)
 - Pulmonary thromboembolism
 - FIP
- Trauma
 - Hemothorax
 - Chylothorax from damage to thoracic duct
- Coagulopathies
 - Vitamin K antagonist rodenticide intoxication



■ **Figure 74.1** Photograph of a 5-month-old male pug that presented for acute onset of anorexia, cough, respiratory difficulty, and pleural effusion.



DIFFERENTIAL DIAGNOSIS

Differentiating Causes

- If there is historical or physical evidence of external trauma, hemothorax, chylothorax, or diaphragmatic hernia should be considered.
- Presence of fever is suggestive of inflammatory, infectious, or neoplastic cause.
- Suspect underlying cardiac cause if murmurs, gallop rhythm, dysrhythmias with or without jugular venous distension or pulsation are present.
- Concurrent ascites is suggestive of FIP, CHF, severe hypoalbuminemia, diaphragmatic hernia, metastatic neoplasia, coagulopathy, or pancreatitis
- Cats with cranial mediastinal masses may have decreased compressibility of the cranial thorax.
- Concurrent ocular changes such as chorioretinitis or uveitis can be found with FIP, fungal disease, rickettsial disease, sepsis, or systemic neoplasia.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- CBC may show inflammatory leukogram in patients with pyothorax, FIP, neoplasia, or lung lobe torsion.

- If pleural effusion is due to hypoalbuminemia, serum albumin is usually less than 1.5 g/dL.
- Polyclonal hyperglobulinemia is usually found in cats with FIP.

Other Laboratory Tests

- If a coagulopathy is suspected (e.g., due to vitamin K antagonist rodenticide exposure), check clotting times (e.g., PT) before performing thoracocentesis.
- Pleural fluid analysis, including physical characteristics (i.e., color, clarity, odor, clots), pH, glucose, total protein, total nucleated cell count, and cytologic examination. See Table 74.1 for information on characterization of pleural fluid.
- In cats, glucose concentration of pleural fluid with pyothorax and malignancy is lower than serum glucose concentration. In most other cases, glucose concentration in pleural fluid is usually equal to levels in serum.
- Because mediastinal lymphosarcoma is often associated with FeLV infection, cats with mediastinal masses should be tested for FeLV.
- FIV test should be done to look for underlying immunosuppression in cats with pyothorax.
- Protein electrophoresis of serum or pleural fluid when FIP is suspected.
- If cardiac disease is suspected, a heartworm test should be considered in dogs and thyroid levels should be evaluated in cats to rule out heartworm disease and hyperthyroidism.
- If pyothorax is suspected, aerobic and anaerobic bacterial culture and sensitivity should be done. Special stains (e.g., gram and acid-fast stains) of pleural fluid should also be considered.
- If chylothorax is suspected, cholesterol and triglyceride levels of the fluid and serum should be performed. An ether clearance test or Sudan stain of the pleural fluid can also aid in the diagnosis of chylothorax.

Imaging

Radiographic Findings

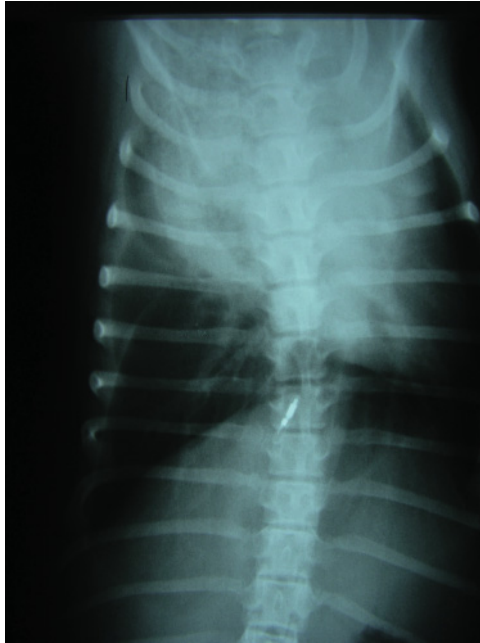
- Should be performed after thoracocentesis in patients with respiratory difficulty and evidence of pleural effusion on physical examination
- Used to confirm pleural effusion
 - Findings include separation of lung borders away from the thoracic wall and sternum by fluid density in the pleural space (Figures 74.2 and 74.3), interlobar pleural fissure lines, silhouetting of fluid with the cardiac and diaphragmatic borders, blunting of the lung margins at the costophrenic angles (on the ventrodorsal view), and widening of the mediastinum (on the ventrodorsal view).
- In patients with fibrosing pleuritis due to chylothorax, pyothorax, or FIP, a rounding of the caudal lung lobe borders can be seen on the lateral view.
- Unilateral effusion is found most commonly with chylothorax, pyothorax, hemothorax, pulmonary neoplasia, diaphragmatic hernias, and lung lobe torsions.

TABLE 74.1 Characterization of Pleural Fluid

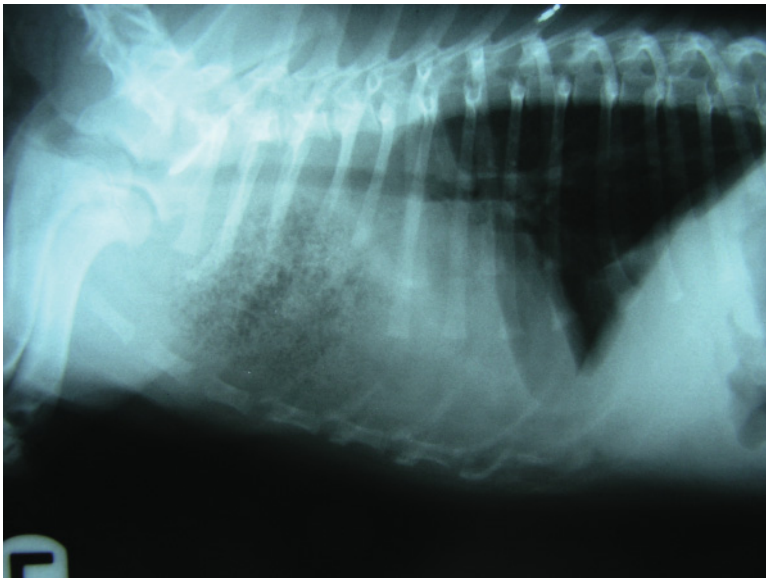
| | Transudate | Modified Transudate | Nonseptic Exudate | Septic Exudate | Chyle | Hemorrhage |
|---------------------------|----------------------------|--|---|--|---|--|
| Color | Colorless to pale yellow | Yellow or pink | Yellow or pink | Yellow to red-brown | Milky white | Red |
| Turbidity | Clear | Clear to cloudy | Clear to cloudy; fibrin | Cloudy to opaque; fibrin | Opaque | Opaque |
| Protein (g/dL) | <2.5 | 2.5–5.0 | 3.0–8.0 | 3.0–7.0 | 2.5–6.0 | >3.0 |
| Nucleated cells/ μ l) | <1,000 | 1,000–7,000 (LSA up to 100,000) | 5,000–20,000 (LSA up to 100,000) | 5,000–300,000 | 1,000–20,000 | Similar to peripheral blood |
| Cytology | Mostly mesothelial cells | Mostly macrophages and mesothelial cells; few nondegenerate PMNs; neoplastic cells in some cases | Mostly nondegenerate PMNs and macrophages; neoplastic cells in some cases | Mostly degenerate PMNs; also macrophages; bacteria | Small lymphocytes, PMNs, and macrophages | Mostly RBCs; macrophages and erythrophagocytosis |
| Disease associations | Hypoalbuminemia; early CHF | CHF; neoplasia; diaphragmatic hernia; pancreatitis | FIP; neoplasia; diaphragmatic hernia; lung lobe torsion | Pyothorax-penetrating chest wound, foreign body, ruptured esophagus, ruptured pulmonary abscess or tumor | Lymphangiectasia, CHF, cranial vena cava obstruction, neoplasia, fungal, heartworm disease, diaphragmatic hernia, lung lobe torsion, trauma | Trauma, coagulopathy, neoplasia, lung lobe torsion |

CHF, congestive heart failure; FIP, feline infectious peritonitis; LSA, lymphoma; PMN, polymorphonuclear cell; RBC, red blood cell.

Modified from Sherding, RG. Diseases of the pleural cavity, In: Sherding, RG, ed. The cat: Diseases and Clinical Management, 2nd ed. New York: Churchill Livingstone, 1994;1061



■ **Figure 74.2** Dorsoventral thoracic radiograph of pug with pleural effusion and abnormal soft tissue density in cranial thorax. Note the rounding and leafing of the lung lobes near the pleural effusion.



■ **Figure 74.3** Lateral thoracic radiograph of pug with pleural effusion and abnormal soft tissue density in cranial thorax. Note the rounding and leafing of the lung lobes near the pleural effusion.

- Post-thoracocentesis radiographs should be taken to evaluate for cardiomegaly, intrapulmonary lesions, mediastinal masses, diaphragmatic hernias, lung lobe torsions, and evidence of trauma.
- Positive contrast peritoneography can be used to diagnose diaphragmatic hernias.
- Positive contrast lymphangiography can be used to evaluate thoracic duct.

Echocardiographic Findings

- Ultrasonographic evaluation of thorax is recommended when cardiac disease, a diaphragmatic hernia, or a cranial mediastinal mass is suspected.

Diagnostic Procedures

- Thoracocentesis—allows the collection of a sample of pleural effusion for fluid analysis to help determine underlying cause
- Exploratory thoracotomy or thoracoscopy can be done to obtain biopsy samples of the lung, lymph nodes, or pleura.

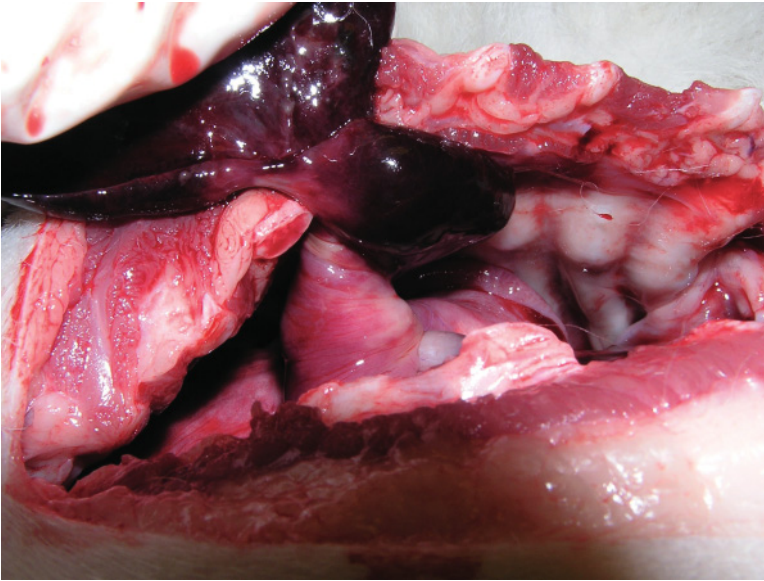


THERAPEUTICS

- Thoracocentesis should be done first in patients with respiratory distress.
- If patient is stable after thoracocentesis, outpatient management is possible in some cases.
- Most patients require hospitalization for monitoring and repeat thoracocentesis as needed.
- For feline patients with pyothorax, indwelling chest tubes are necessary; in dogs, most animals require surgical intervention for successful treatment of pyothorax.
- Treatment for underlying disease is needed to prevent further fluid accumulation.
- Surgery is indicated for some neoplasias, diaphragmatic hernias, some cases of pyothorax (e.g., for foreign body removal), lung lobe torsion (Figure 74.4), and some cases of chylothorax.
- For cases where fluid continues to accumulate despite treatment, repeated thoracocenteses or other palliative options such as placement of a subcutaneous vascular access port connected to an intrathoracic drain should be considered.

Drug(s) of Choice

- Treatment varies with underlying cause.
- Diuretics should only be used for patients with diseases that cause fluid retention and volume overload (e.g., CHF); otherwise, diuretics are largely ineffective for the treatment of pleural effusion not associated with CHF



■ **Figure 74.4** Necropsy photograph of lung lobe torsion that caused the pleural effusion. Lung lobe torsion has been reported in young pugs and is just one of the many causes of pleural effusion in dogs and cats.



COMMENTS

Patient Monitoring

- Radiographic evaluation is used to assess the efficacy of treatment in most cases.

Possible Complications

- Death due to respiratory compromise
- Reexpansion pulmonary edema can occur after removal of pleural effusion.
- Iatrogenic pneumothorax during thoracocentesis

Expected Course and Prognosis

- Variable with underlying cause; guarded to poor in most cases

Abbreviations

- CBC: complete blood count
- CHF: congestive heart failure
- FeLV: feline leukemia virus
- FIP: feline infectious peritonitis
- FIV: feline infectious virus
- pH: acid-base status
- PT: prothrombin time

Suggested Reading

- Cahalane, AK, Flanders, JA, Steffey, MA, et al. Use of vascular access ports with intrathoracic drains for treatment of pleural effusion in three dogs. *J Am Vet Med Assoc* 2007;230(4):527–531.
- Padrid, P. Pulmonary diagnostics. In: August, JR, ed. *Consultations in Feline Internal Medicine* 3rd ed., 292–302. Philadelphia: Saunders, 1997.
- Sherding, RG, and Birchard, SJ. Pleural effusion. In: Birchard, SJ, and Sherding, RG, eds. *Saunders Manual of Small Animal Practice*, 2nd ed., 670–680. Philadelphia: Saunders, 2000.

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Special consideration to Francis W. K. Smith, Jr.

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Francis W. K. Smith

Pneumonia—Aspiration



DEFINITION/OVERVIEW

- Aspiration pneumonia is caused by inhalation of liquid or particulate matter into the lower respiratory tract that results in inflammation/infection of the pulmonary parenchyma. Aspiration pneumonia is far more common in the dog than the cat.



ETIOLOGY/PATHOPHYSIOLOGY

- In the oronasal pharynx, the close proximity of the upper airway to the proximal aspect of the GI tract make animals, especially dogs, susceptible to inhalation of regurgitated and vomited materials, and subsequent aspiration pneumonia.
- Aspiration pneumonia is commonly associated with vomiting, esophageal and laryngeal disorders, neurologic disease, and anesthesia.

Systems Affected

- Cardiovascular—Tachycardia possible to compensate for hypoxia.
- GI—May have a history of GI symptoms such as vomiting and regurgitation.
- Hemic/Lymphatic/Immune—May or may not have leukocytosis, left shift.
- Musculoskeletal—May be weak secondary to hypoxia.
- Nervous—Likely depressed or obtunded due to hypoxia.
- Respiratory—Coughing, gagging, and tachypnea often present.
- Skin/Exocrine—Fever is possible, if hypoxia is severe enough grey, pale and cyanotic mucus membranes can be present.



SIGNALMENT/HISTORY

- A history of vomiting or regurgitation shortly followed by respiratory distress is typical of aspiration into the lower airways. Additional common history includes laryngeal or esophageal disorders and recent anesthesia. Older dogs and larger breeds are reported to most commonly develop aspiration pneumonia. Aspiration may also be a silent event, without a history of vomiting or regurgitation.

Risk Factors/Causes

- Animals with megaesophagus and laryngeal dysfunction are at significant risk for aspiration pneumonia. The aspiration event may not be observed in patients with laryngeal and esophageal abnormalities, but in these patients an increased index of suspicion is always present. Postoperative and heavily sedated patients often have an impaired gag reflex making them susceptible to aspiration and subsequent pneumonia.
- In addition to anesthetized patients, those suffering from neuromuscular blockade or paralysis (e.g., botulism, tick paralysis, coonhound paralysis) may develop an impaired gag reflex and are also susceptible to the development of aspiration pneumonia.
- Animals that require mechanical ventilation also have an increased risk of aspiration because oropharyngeal flora may be transported to the lower airways during intubation and result in airway colonization.
- Nasogastric feeding tubes that have been misplaced or displaced can also predispose to aspiration pneumonia.

Historical Findings

- Commonly reported history includes recent vomiting or procedures requiring anesthesia. It is also important to quiz owners on subtle changes in their pet's attitude, voice, appetite and for presence of a cough, which may be indicators of laryngeal dysfunction as well as aspiration.



CLINICAL FEATURES

- Increased respiratory rate and fever are present in only approximately one-third of dogs that present with aspiration pneumonia, making them poor indicators of this disease.
- Abnormal lung sounds are commonly found during physical examination.
- Commonly described physical examination abnormalities are:

Auscultation

- Abnormal lungs sounds, most commonly crackles and loud lung sounds, have been reported to be the most consistent physical examination finding in dogs with any type of pneumonia. The lack of normal or abnormal sounds may be indicative of complete consolidation of that area of lung, which is common in aspiration.

Chest Percussion

- Percussion of the thorax may be helpful in identifying areas of lung consolidation. Percussion of consolidated areas of lung elicits a low pitched or dull sound.

Tracheal Palpation

- Tracheal palpation can be utilized to elicit a cough and confirm epithelial irritation. Pneumonia is most often associated with increased secretions and a moist, or productive cough.

Oral/Pharyngeal Examination

- Information concerning laryngeal/pharyngeal anatomy and function is sought on examination. The following abnormalities may be noted on close inspection and can be associated with pneumonia: excess secretions, severe dental or tonsillar disease, masses, an abnormal gag reflex, or the presence of foreign material or gastric contents.



DIFFERENTIAL DIAGNOSIS

- Dogs—Bacterial/fungal/viral pneumonia, near drowning, heartworm disease, pulmonary thromboembolism, electrocution, smoke inhalation, congestive heart failure, collapsing trachea, allergic airway disease, chronic bronchitis.
- Cats—Congestive heart failure, allergic airway disease (asthma), pyothorax.



DIAGNOSTICS

Thoracic Radiographs

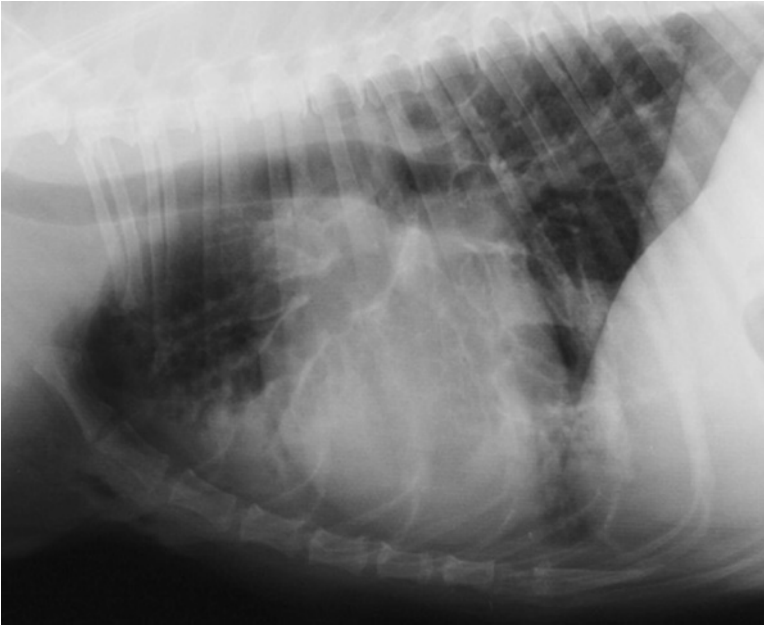
- Key in diagnosing aspiration pneumonia.
- Three views (dorsoventral or ventrodorsal, right and left lateral) of the thorax are recommended in order to examine all lung fields.
- Aspiration pneumonia is classically located in dependent lung lobes, right middle, left cranial, and right cranial.
- Common radiographic findings include air bronchograms (Figures 75.1 and 75.2) and alveolar infiltrates, from patchy to lobar consolidation.

Additional Base Line Testing

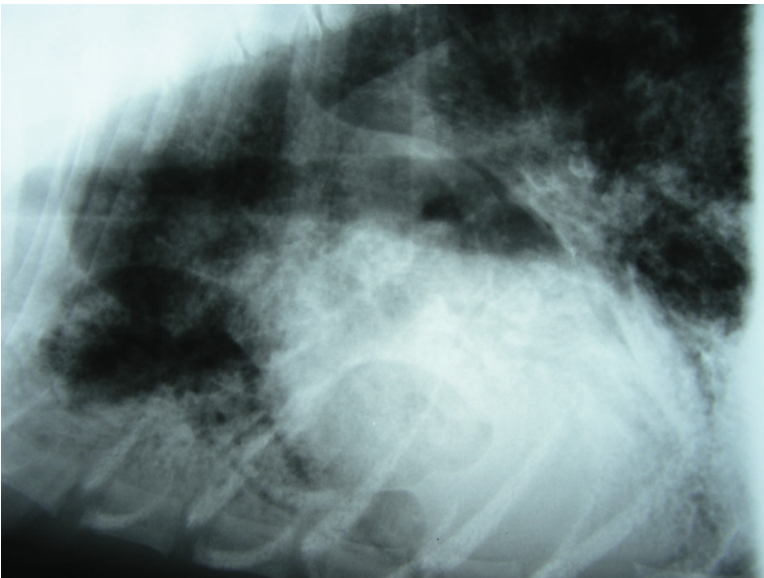
- CBC, chemistry, and urinalysis, urine culture, fecal examination
- Ancillary testing to rule out diseases that may increase susceptibility to aspiration such as ACH receptor antibody titers to diagnose myasthenia gravis

Advanced Diagnostics

- Arterial blood gas can be utilized to objectively (A-a gradient) monitor disease progression/resolution, and response to therapeutics.



■ **Figure 75.1** Lateral thoracic radiograph showing air bronchograms and bronchiectasis in right cranial lung lobe of a dog.



■ **Figure 75.2** Severe aspiration pneumonia in the right middle and cranial lung lobes of a Great Dane that ingested 1 gallon of used peanut oil from a turkey fryer after Thanksgiving dinner was served.

- Pulse oximetry can also be used to monitor hypoxia and need for/response to oxygen supplementation in a non-invasive manner.
- BAL is considered the best method for obtaining samples from the deep lung but should only be performed immediately after aspiration to alleviate airway obstruction by foreign material or to obtain cultures when disease does not respond to standard treatment.
- Transtracheal wash is not recommended unless obtaining cultures, BAL preferred; no visualization of lower airways.
- Culture and sensitivity are recommended on samples obtained from airways; quantitative cultures are best to allow differentiation between normal flora and infection. Cultures consistent with infection contain $>1.7 \times 10^3$ CFU.
- Gram-stain samples are helpful if culture is negative.



THERAPEUTICS

Antibiotics

- Pending culture and sensitivity results, bactericidal antibiotics with gram-negative spectrum should be utilized when aspiration is suspected. Oral antibiotics may need to be continued for extended periods of time (4 to 6 weeks after discharge). Antibiotic therapy should be continued 1 to 2 weeks past resolution of radiographic and clinical signs.

Fluid Therapy

- Tracheobronchial secretions are approximately 95 percent water; systemic dehydration results in increased secretion viscosity, retention in the lower airways. Decreasing the viscosity of secretions will assist in their clearance and the resolution of pneumonia.

Oxygen

- Animals with aspiration pneumonia can have lower $\text{PaO}_2 < 60$ mm Hg, lower $\text{SaO}_2 < 90$ to 92 percent, and significantly greater A-a gradients should be supplemented with oxygen when hypoxia is documented.

Nebulization

- Aerosol therapy has been utilized in pneumonic dogs in an attempt to decrease the viscosity of infectious secretions and improve mucociliary clearance.
- Sterile saline is currently the only fluid recommended for use in patients being nebulized.
- Ultrasonic nebulizers producing particles that range between 0.5 and $3.0\mu\text{m}$ in size (mass median diameter) are necessary to ensure that fluid particles reach the lower airways.

- Nebulization is performed by placing the patient in a sealed cage for 30 to 45 minutes three to four times daily.
- Potential complications associated with cage nebulization include overhydration and overheating in very small patients as well as bacterial contamination.
- Nebulization of antibiotics, mucolytics, or other drugs are not routinely recommended with the exception of *Bordetella* (Gentamycin 7 mg/kg).

Physiotherapy

- Coupage is best described as physical therapy consisting of a firm clap (hands are cupped) on the lateral aspects of the thoracic cage. The percussion of the thoracic cage induces cough and serves to loosen and clear secretions. Coupage should be performed for 5 to 10 minutes three to four times daily.

Diet

- Malnutrition has been shown to alter pulmonary defense mechanisms, resulting in impaired clearance of organisms and foreign material. Once GI symptoms have been addressed enteral nutrition should be attempted. In severe cases, parenteral nutrition may be necessary.

Activity

- Activity within the limits of the animal's pulmonary function should be encouraged, as it helps mobilize pulmonary secretions.

Surgical Considerations

- Lung lobectomy has been reported as a treatment for pneumonia, of various etiologies, that is nonresponsive to medical therapy. Lung lobectomy should be considered in chronic cases of aspiration pneumonia when a foreign body is suspected, or pneumonia is chronic or reoccurring.



COMMENTS

- Radiographic changes can lag behind clinical changes up to 48 hours; the most reliable, objective way to gauge clinical changes are with arterial blood gases. Hypoxic animals not responding to oxygen therapy alone could require ventilatory support.

Client Education

- Monitor for return of respiratory difficulty, anorexia, vomiting, and fever.

Patient Monitoring

- The A-a gradient is the most objective way to monitor disease progression. Unless there is an acute change in the animal's condition, it is calculated once daily.
- Radiographs are usually repeated at two week intervals once the animal is discharged.

Prevention/Avoidance

- If associated with anesthesia make sure endotracheal tube cuffs are functioning properly.

Possible Complications

- Pneumonia may not resolve with medical management, especially if a foreign body is present, and surgical options may need to be considered.

Expected Course and Prognosis

- Aspiration pneumonia without a permanent underlying cause such as megaesophagus is likely to resolve when treated appropriately; clinical improvement is often seen within 24 to 72 hours. Animals with diseases causing esophageal and laryngeal dysfunction are always susceptible to aspiration and many do not resolve. Greater than 75 percent of patients suffering from aspiration pneumonia are reported to survive.

Abbreviations

- A-a: alveolar-arterial
- ACH: acetylcholine
- BAL: bronchoalveolar lavage
- CBC: complete blood count
- GI: gastrointestinal
- PaO₂: partial pressure of oxygen in blood
- SaO₂: oxygen saturation in blood

See Also

- Pneumonia—Bacterial

Suggested Reading

- Barton, L. Aspiration pneumonia. In: King, LG, ed. *Textbook of Respiratory Diseases in Dogs and Cats*, p. 422. St. Louis: Elsevier, 2004.
- Hawkins, EC. Aspiration pneumonia. In: Bonagura, JD, ed. *Current Veterinary Therapy XII*, p. 915. Philadelphia: Saunders, 1995.
- Kogan, DA, Johnson, LR, Janfrey, KE, et al. Clinical, clinicopathologic, and radiographic findings in dogs with aspiration pneumonia: 88 cases (2004–2006). *J Am Vet Med Assoc* December 2008;233(11):1742–1747.
- Kogan, DA, Johnson, LR, Janfrey, KE, et al. Etiology and clinical outcome in dogs with aspiration pneumonia: 88 cases (2004–2006). *Am Vet Med Assoc* 2008;233(11):1748–1755.

Author: Adam J Reiss

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Eleanor C Hawkins

Pneumonia—Bacterial



DEFINITION/OVERVIEW

- Defined as any inflammation of the lung parenchyma that results in the filling of the alveolar air spaces with exudate. Bacterial colonization of the lung is the most common cause most of pneumonia in small animals. Bacterial pneumonia occurs more commonly in dogs than in cats.



ETIOLOGY/PATHOPHYSIOLOGY

- Animals that develop bacterial pneumonia often have impaired pulmonary defenses. Inhibition of pulmonary immunity is often caused by underlying metabolic diseases (such as diabetes mellitus and hyperadrenocorticism), lower airway disease (chronic bronchitis, ciliary dyskinesia), laryngeal and esophageal dysfunction, as well as those from exposure to environmental pathogens (*Bordetella*). Additionally pathogenic bacteria may have specific physical and biochemical properties that allow them to thwart lower airway defenses and cause disease. The source of invading bacteria is often from the oronasal and pharyngeal regions, upper GI tract, and normal lower airway flora. Hematogenous spread has also been proposed as a cause of bacterial pneumonia and is reported to occur more commonly in cats.

Systems Affected

- Cardiovascular—Tachycardia possible to compensate for hypoxia
- Hemic/Lymphatic/Immune—May or may not have leukocytosis with a left shift
- Musculoskeletal—May be weak secondary to hypoxia
- Nervous—Likely depressed or obtunded due to hypoxia
- Respiratory—Coughing, gagging, and tachypnea with or without expectoration of debris or mucus often present
- Skin/Exocrine—Fever is possible, if hypoxia is severe enough grey, pale and cyanotic mucous membranes can be present.



SIGNALMENT/HISTORY

- No sex or breed predispositions.

Risk Factors/Causes

- Metabolic disorders—diabetes mellitus or hyperadrenocorticism
- Acquired diseases—myasthenia gravis, polyradiculoneuritis, or tick paralysis
- Immunosuppression—secondary to chemotherapy or other infections (i.e., viral, fungal)
- Laryngeal and esophageal disorders—laryngeal paralysis or megaesophagus
- Other sites of infection—dermatologic, phlebitis, oral, urinary tract, or reproductive tract
- Exposure to other pets—shelters, boarding grooming, shows, or dog parks
- Vomiting

Historical Findings

- Coughing, nasal discharge, tachypnea, orthopnea, anorexia, dehydration, or weight loss



CLINICAL FEATURES

- No single clinical parameter is pathognomonic in the diagnosis of bacterial pneumonia.

Dogs

- Fever reported in <50 percent of dogs with bacterial pneumonia; cough, tachypnea, nasal discharge.
- Auscultation of all lung fields is an important part of the diagnosis of pneumonia. Common abnormalities detected during auscultation commonly include crackles and loud lung sounds. Decreased sounds may be indicative of complete consolidation of that area of lung, which is common when aspiration is an underlying cause of bacterial pneumonia.
- Tracheal palpation can be utilized to elicit a cough and confirm tracheal irritation.
- Pneumonia is most often associated with increased secretions and a moist, or productive cough.
- Oropharyngeal examination can also provide information with regard to bacterial pneumonia. Laryngeal and pharyngeal anatomy and function can be assessed, as well as the condition of the dentition and gums. Additional oropharyngeal abnormalities that may be noted and can be associated with pneumonia include: excess secretions, tonsillar disease, masses, an abnormal gag reflex, or the presence of foreign material or gastric contents.

Cats

- May have clinical signs similar to dogs or none at all.
- Observe for oral erosions and ocular signs consistent with URI, which may be an underlying or associated disease.



DIFFERENTIAL DIAGNOSIS

- Dogs—Bacterial/fungal/viral pneumonia, near drowning, heartworm disease, pulmonary thromboembolism, electrocution, smoke inhalation, congestive heart failure, collapsing trachea, allergic airway disease, or chronic bronchitis.
- Cats—Congestive heart failure, allergic airway disease (asthma), or pyothorax.



DIAGNOSTICS

Thoracic Radiographs

- Key in diagnosing pneumonia.
- Ventrodorsal or dorsoventral, and both left and right lateral views are recommended to examine all lung fields.
- Common radiographic findings include air bronchograms and alveolar infiltrates, from patchy to lobar consolidation (Figure 76.1). Pleural effusion is uncommon but may be present in severe cases.

Additional Base Line Testing

- CBC, chemistry, urinalysis, urine culture, and fecal examination



■ **Figure 76.1** Alveolar lung pattern in right caudal lung field shown in this ventrodorsal thoracic radiograph from a dog with pneumonia.

- Ancillary testing to rule out diseases that may increase susceptibility to aspiration such as ACH receptor antibody titers to diagnose myasthenia gravis

Advanced Diagnostics

- Arterial blood gas can be utilized to objectively (A-a gradient) monitor disease progression/resolution, and response to therapeutics.
- Pulse oximetry can also be used to monitor hypoxia and need for/response to oxygen supplementation in a non-invasive manner.
- BAL is considered the best method for obtaining culture and cytology samples from small airways, alveoli and pulmonary interstitium.
- Transtracheal wash does not provide visualization of the airways; samples collected are from larger airways.
- Culture and sensitivity are recommended on samples obtained from airways; quantitative cultures are best because they allow differentiation between normal flora and infection. Cultures consistent with infection contain $>1.7 \times 10^3$ CFU.
- Gram-stain samples are helpful if culture is negative.



THERAPEUTICS

- Treatment objective are to improve oxygenation and eliminate the infection. Concurrent treatment of underlying and secondary diseases may be necessary.

Antibiotics

- Pending culture and sensitivity results, bactericidal antibiotics with a broad-spectrum of activity should be utilized. Severe case should be started on intravenous antibiotics to provide good penetration of the pulmonary parenchyma. Maximum doses and dosing intervals should be utilized to ensure effectiveness. Mild cases can be started on oral antibiotics. Drug classes commonly effective in treating bacterial pneumonia include cephalosporins, potentiated penicillins, and fluoroquinolones. Oral antibiotics may need to be continued for extended periods of time (4 to 6 weeks after discharge). Antibiotic therapy should be continued 1 to 3 week past resolution of radiographic and clinical signs.

Fluid Therapy

- Tracheobronchial secretions are approximately 95 percent water; systemic dehydration results in increased secretion viscosity, retention in the lower airways, and often ventilation perfusion abnormalities. Fluids should be administered to correct dehydration and maintain hydration status until animal can sustain itself.

Oxygen

- Animals with pneumonia can have lower $\text{PaO}_2 < 60 \text{ mmHg}$, lower $\text{SaO}_2 < 90$ to 92 percent, and significantly greater A-a gradients and should be supplemented with oxygen when hypoxia is documented.

Nebulization

- Aerosol therapy has been utilized in pneumonic dogs in an attempt to decrease the viscosity of infectious secretions and improve mucociliary clearance.
- Sterile saline is currently the only fluid recommended for use in patients being nebulized.
- Ultrasonic nebulizers that produce particles that range between 0.5 and $3.0 \mu\text{m}$ in size (mass median diameter) are necessary to ensure that fluid particles reach the lower airways.
- Nebulization is performed by placing the patient in a sealed cage for 30 to 45 minutes up to three to four times daily.
- Potential complications associated with cage nebulization include overhydration and overheating in very small patients as well as bacterial contamination.
- Nebulization of antibiotics, mucolytics, or other drugs are not routinely recommended with the exception of *Bordetella*. Cases of *Bordetella* that are resistant to systemic antibiotics may respond to the local effects of those that are nebulized (Gentamycin 7 mg/kg diluted with sterile saline).

Physiotherapy

- Coupage is best described as physical therapy consisting of a firm clap (hands are cupped) on the lateral aspects of the thoracic cage. The percussion of the thoracic cage serves to loosen and help clear secretions by inducing coughing. Coupage should be performed for 5 to 10 minutes three to four times daily.

Diet

- Malnutrition has been shown to alter pulmonary defense mechanisms and result in impaired clearance of organisms and foreign material. Once GI symptoms have been addressed enteral nutrition should be attempted.
- In severe cases, the use of parenteral nutrition may be required.

Activity

- Activity within the limits of the animal's pulmonary function should be encouraged because it helps mobilize pulmonary secretions.

Surgical Considerations

- Lung lobectomy has been reported as a treatment for pneumonia, of various etiologies, that is nonresponsive to medical therapy. Lung lobectomy should be

considered in chronic cases of lobar pneumonia when an aspirated foreign body is suspected as the underlying cause.



COMMENTS

- Radiographic changes can lag behind clinical changes up to 48 hours; the most reliable, objective way to gauge clinical changes is to obtain arterial blood gasses. Hypoxic animals not responding to oxygen therapy alone could require ventilatory support.

Client Education

- Monitor for return of respiratory difficulty, anorexia, vomiting, and fever.

Patient Monitoring

A-a Gradient

- The A-a gradient is the most objective way to monitor disease progression. Unless there is an acute change in the animal's condition, it is recommended that the A-a gradient be calculated once daily.
 - To calculate the A-a gradient, obtain an arterial blood sample. The values of significance on the arterial blood sample include the PaO_2 , barometric pressure, and the PaCO_2 .
 - "Big A" (A) is the amount of oxygen available in the alveolus and is dependent on the FiO_2 (on room air, the FiO_2 is 21 percent or 0.21), the barometric pressure (think of this as the force that can help push the air into the lungs), and the diffusion capacity of air itself. Because CO_2 diffuses more readily than oxygen, there is a calculation that takes into consideration the CO_2 component.
 - "Little a" or (a) is the amount of oxygen actually in the bloodstream.
 - To calculate the A-a gradient, first calculate A.
 - $A = \text{FiO}_2 (\text{barometric pressure} - \text{water vapor pressure}) - \text{PaCO}_2/0.8$
 - Water vapor pressure is a constant and is equal to 47.
 - Next, subtract PaO_2 from A, and the value is equal to the A-a gradient.
 - The A-a gradient allows you to determine the degree of diffusion impairment between the amount of oxygen available to the lung, and that which actually enters the bloodstream.
 - Normal values are < 10 , 10 to 15 suggest moderate diffusion impairment, and > 20 is suggestive of acute respiratory distress syndrome.

$\text{PaO}_2/\text{FiO}_2$ Ratio

- In an animal that is receiving supplemental oxygen, the A-a gradient will be negative. Instead, one must calculate the $\text{PaO}_2/\text{FiO}_2$ ratio.

- For facemasks, oxygen supplementation catheters, and hood or cage oxygen, the FiO_2 can be estimated at 40 percent or 0.40. Ideally, measure the FiO_2 with an oxygen meter.
- Normal calculated $\text{PaO}_2/\text{FiO}_2$ values are > 400 . Values in between 200 and 300 are suggestive of acute lung injury. Values < 200 are suggestive of acute respiratory distress syndrome.

Radiographs

- Radiographs are usually as needed while the patient is in the hospital and repeated at 2-week intervals once the animal is discharged.

Prevention/Avoidance

- Pet should be vaccinated for any infectious diseases that can predispose to bacterial pneumonia. Underlying diseases and conditions such as dental abscesses, diabetes, and hyperadrenocorticism should be addressed.

Possible Complications

- Severe pneumonia can result in pulmonary abscesses, pneumothorax and chronic airway issues; surgery and long-term/ongoing therapy may be required.

Expected Course and Prognosis

- A good prognosis can be given to those patients that show improvement of respiratory function within 24 to 72 hours of beginning appropriate antibiotic therapy.
- Poor outcomes on the other hand can be predicted in those animals that have antibiotic resistant organisms cultured, underlying diseases that can not be resolved (e.g., laryngeal paralysis, megaesophagus), the presence of concurrent disease (e.g., fungal and viral infections, neoplasia), and hypercarbia on presentation.

Abbreviations

- A-a: alveolar-arterial
- ACH: acetylcholine
- BAL: bronchoalveolar lavage
- CBC: complete blood count
- FiO_2 : fraction of inspired oxygen
- GI: gastrointestinal
- PaO_2 : partial pressure of oxygen in blood
- PaCO_2 : partial pressure of carbon dioxide in blood
- SaO_2 : oxygen saturation in blood
- URI: upper respiratory infection

See Also

- Pneumonia—Aspiration

Suggested Reading

- Brady, CA. Bacterial pneumonia in dogs and cats. In: King, LG. *Textbook of Respiratory Diseases in Dogs and Cats*, p. 412. St. Louis: Elsevier, 2004.
- Ford, RB. Bacterial pneumonia. In: Bonagura, JD, and Twedt, DC, ed. *Current Veterinary Therapy XIV*, p. 658. Philadelphia: Saunders, 2009.
- Jameson, PH, King LA, Lappin, MR, et al. Comparison of clinical signs, diagnostic findings, organisms isolated, and clinical outcome in dogs with bacterial pneumonia: 93 cases (1986–1991). *J Am Vet Med Assoc* 1995;206:206.
- Peeters, DE, McKiernan, BC, Weisiger, RM, et al. Quantitative bacterial cultures and cytological examination of bronchoalveolar lavage specimens in dogs. *J Vet Intern Med* 2000;14:534.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Philip Roudebush

Pneumothorax



DEFINITION/OVERVIEW

- Free air that accumulates in the pleural cavity in between the lungs and the pleura.
- Can be spontaneous (rare) or more commonly caused by trauma.
- Spontaneous pneumothorax causes air to accumulate in the pleural space outside of the lungs without trauma.
- Traumatic pneumothorax is air that accumulates in the pleural spaces as a result of trauma to the trachea, mainstem bronchi, lungs, or thoracic wall.
- Pneumothorax can also be categorized as being closed or open.
- Closed pneumothorax occurs when there is no break in the integrity of the thoracic wall.
- Open pneumothorax is associated with a break in the integrity of the thoracic wall, such that atmospheric pressure comes in contact with intrapleural pressure, and causes the lungs to collapse.
- A tension pneumothorax results when damage to the bronchi or lungs causes a flap of tissue that acts as a valve. When the animal inhales, air leaks from the flap into the pleural space. Upon exhalation, the flap of tissue closes and prevents the air from leaving the pleural space. Pleural pressure continues to accumulate until there is severe pressure on the cranial vena cava that prevents blood from returning to the right-sided heart, thus impairing cardiac preload. As a result, cardiac output and blood pressure are adversely compromised. The animal with a tension pneumothorax can rapidly deteriorate and die without immediate aggressive intervention.



ETIOLOGY/PATHOPHYSIOLOGY

- The pleural cavity is lined with a thin layer of fluid and tissue called the parietal and visceral pleura. Normally, the visceral and parietal pleura and the lungs are contiguous, and freely move the lungs against the thoracic wall and diaphragm during normal respiration.
- Pressure in the pleural space is normally subatmospheric. An animal actively draws in a breath to expand the lungs, and then relaxation of the thoracic wall and diaphragm allows air within the lungs to leave the alveoli and return to the atmosphere via the trachea and upper airways. When air escapes from the lungs into the pleural

space, it accumulates in between the parietal and visceral pleura, and causes the lungs to collapse.

- Collapse of any portion of the lungs causes that portion to be perfused but not participate in alveolar gas exchange, or ventilation. This results in a ventilation-perfusion mismatch and hypoxemia.
- A pneumothorax can be bilateral if the mediastinum is open, or unilateral, if the mediastinum on both sides of the thorax does not communicate.

Systems Affected

- Cardiovascular
- Respiratory

Incidence/Prevalence

- Unknown
- It has been documented in more than 40 percent of cases of thoracic trauma, and 10 to 20 percent of cases of trauma caused by contact with automobiles.



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predilection

- Spontaneous pneumothorax is documented more commonly in large, deep-chested breeds of dog.

Historical Findings

- In cases of traumatic pneumothorax, recent trauma may be documented, either fall from height, motor vehicle accident, encounter with a large animal, or recent anesthesia with endotracheal intubation. Iatrogenic pneumothorax also can be caused by jugular venipuncture (although rare) or thoracocentesis.
- In spontaneous pneumothorax, historically there may be an acute onset of cough, cyanosis or pale mucous membranes, respiratory difficulty, exercise intolerance, lethargy, inappetence, or orthopnea, which may or may not be associated with previous history of respiratory disease.

Physical Examination

- Rapid, shallow, restrictive respiratory pattern with muffled lung sounds, primarily dorsally but may be muffled in any area of the thorax. Tachypnea, orthopnea, extended neck, cyanosis, and billowing of the skin/cheeks in dogs, or obvious movement of the copulas, in front of the shoulder blades at the thoracic inlet in cats.



■ **Figure 77.1** Open pneumothorax caused by severe thoracic bite wounds. Notice the lung visible outside of the thoracic cavity.

- When pneumothorax has been caused by a traumatic event, other signs referable to trauma may be present, including obvious hemorrhage or abrasions, rib fractures or other injuries to the thoracic wall, paradoxical chest wall motion in cases of flail chest, abrasions, frayed toenails, bite wounds, tachycardia, hypotension.
- In cases of open pneumothorax, bite wounds or penetrating injuries to the thoracic wall may be visible (Figure 77.1). If recent anesthesia and endotracheal intubation caused the pneumothorax, subcutaneous emphysema may be present.

Risk Factors/Causes

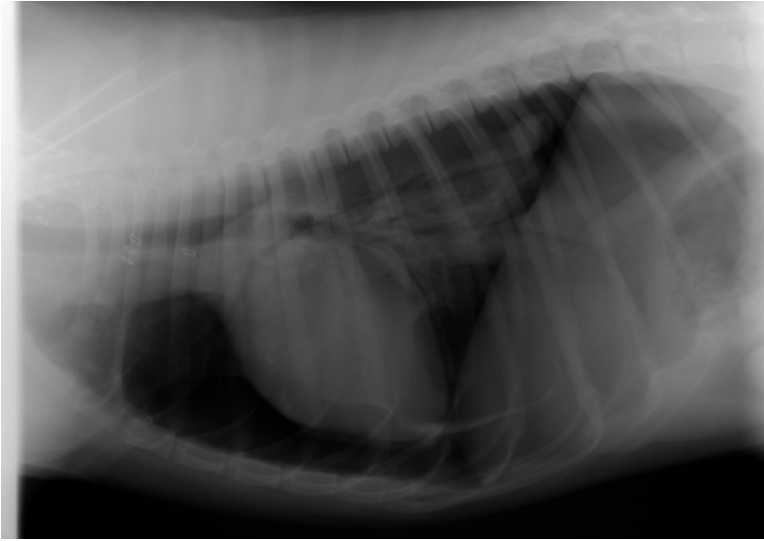
- Blunt or penetrating trauma to the thorax or upper airways, penetrating cervical injuries, thoracocentesis, perforation of the esophagus from esophageal foreign bodies, migrating foreign bodies (grass awns, porcupine quills), neoplasia, pulmonary abscesses, parasitic infections (paragonimus), cysts (congenital), pulmonary bullae, emphysema
- Trauma, particularly in animals allowed to roam near open roads or near large animals; recent thoracocentesis, respiratory pathology, grass awns, encounters with porcupines, iatrogenic with overinflation of endotracheal tube cuff



DIFFERENTIAL DIAGNOSIS

Diagnosis

- Differential diagnoses for pneumothorax include other forms of pleural space disease, including pleuritis, pleural effusion, pulmonary contusions, diaphragmatic hernia, neoplasia, pneumonia, and pleural hemorrhage.



■ **Figure 77.2** Lateral thoracic radiograph of an animal with pneumothorax. Notice that the cardiac silhouette is elevated away from the sternum, and the lungs appear grayer in appearance, due to collapse and lack of air within the alveoli.



■ **Figure 77.3** Dorsoventral thoracic radiograph of same dog with pneumothorax caused by migration of a porcupine quill.

Differentiating Causes

- Pneumothorax can be differentiated from other caused of pleural space disease and restrictive respiratory pattern by a lateral (Figure 77.2) and dorsoventral thoracic radiograph (Figure 77.3).



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- CBC, biochemistry, and urinalysis are usually unrewarding unless there is an infectious etiology that is associated with pulmonary pathology and sometimes a neutrophilic leukocytosis.

Other Laboratory Tests

- Arterial blood gases show hypoxemia (decreased PaO_2). Hypercapnia or hypocapnia may be present.
- Hypoxemia and $\text{SpO}_2 < 90$ percent with pulse oximetry.

Diagnostic Procedures

Imaging

- Thoracic radiographs should be delayed until the patient is more stable, and attempts have been made to treat the pneumothorax prior to making a definitive diagnosis with radiography. Remember that thoracocentesis can be both diagnostic as well as therapeutic in cases of pneumothorax.
- Thoracic radiographs may reveal free air within the pleural space, as evidenced by retraction of the lungs away from the thoracic wall, and elevation of the cardiac silhouette from the sternum on a lateral view. The pulmonary vasculature will not be visible at the level of the thoracic wall. In cases of pneumomediastinum, the cranial vena cava, esophagus, and aorta will be visible. Rib fractures, foreign bodies, such as bullets, may be visible in cases of traumatic pneumothorax. If such findings are not present, often thoracic radiographs should be repeated after therapeutic thoracocentesis, to evaluate the lung for parenchymal disease such as bullae.
- CT scanning: May be sensitive for identifying both pneumothorax, as well as parenchymal pathology. A disadvantage of CT is the frequent need for heavy sedation or anesthesia in veterinary patients.



THERAPEUTICS

- Treatment of pneumothorax largely depends on the degree of hypoxia and respiratory difficulty, severity of lung collapse, response to therapy, and whether the pneumothorax recurs.

- Initially, supplemental oxygen should be administered as rapidly as possible and with the least stressful method available.

Thoracocentesis

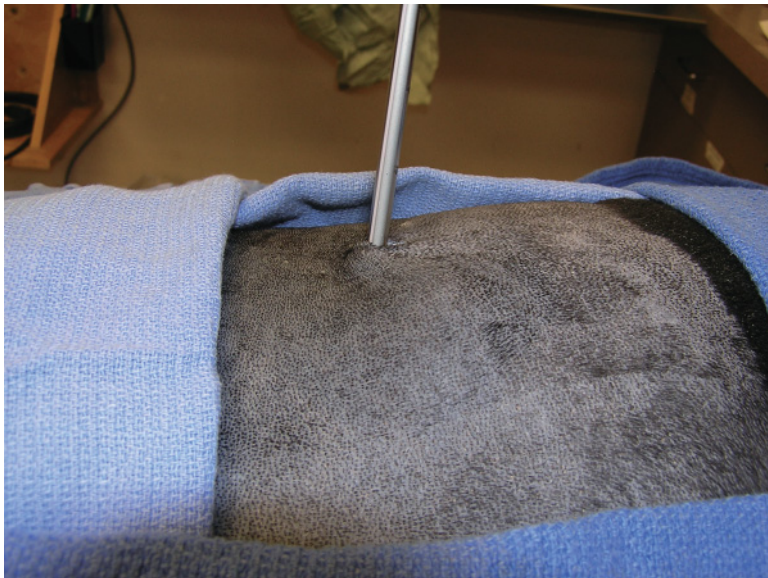
- Therapeutic thoracocentesis should be performed. To perform thoracocentesis, clip a square in the middle of the lateral thoracic wall, envisioning the ribcage as a box. Clip a box in the middle of the box, then aseptically scrub the area. Next, connect a hypodermic needle (usually 22-gauge three-quarter- to one-and-one-half-inch needle, depending on the size and degree of obesity of the patient) to a length of intravenous extension tubing, to a three-way stopcock, to a 35- to 60-ml syringe. With the bevel of the needle facing down, insert the needle perpendicular to the thorax, in the middle of the box, in between rib spaces (Figure 77.4). Once the needle has entered the pleural space, direct the needle so that it sits parallel with the thoracic wall. The bevel of the needle is now facing the inside of the pleural space and ready to aspirate air. The needle can be swept around like the hands of a clock, always parallel with the thoracic wall, to avoid iatrogenic puncture of the lungs. In smaller patients, such as neonates, a butterfly catheter and smaller needle can be used.
- As a rule of thumb, always perform bilateral thoracocentesis, in the event that the mediastinum does not communicate. If you cannot obtain negative pressure and fully evacuate the air from the pleural space, or if the air reaccumulates more than once, a thoracostomy tube should be placed.



■ **Figure 77.4** Inserting a 22-gauge hypodermic needle into the pleural space for thoracocentesis.

Thoracostomy Tube Placement

- In the event that a thoracostomy tube needs to be placed, clip the entire lateral thorax from the level of the vertebrae to the sternum, and from the 1st through 13th ribs. Aseptically scrub the clipped area, and then drape the area with sterile field towels. Ideally, the animal should be anesthetized and intubated, so that you can maintain an airway and breathe for the patient, if necessary. Have an assistant pull the skin on the lateral thoracic wall cranially and ventrally, toward the elbow. This will facilitate making a tunnel through which the tube is placed. Trocarized thoracic drainage catheters are manufactured from a variety of manufacturers. Any thoracic drainage tube should be, at minimum, the size of a mainstem bronchus, and not smaller, such that if a mainstem bronchus is the location of air leakage, suctioning the thorax through the tube can keep up with the air that is accumulating in the pleural space. Make a nick incision at the dorsal aspect of the 12th rib, then tunnel the tube under the skin, so that the tube can enter the 8th to 10th intercostal space. The trocarized thoracic catheters will need to be pulled so that the catheter is perpendicular with the thoracic wall (Figure 77.5). Grasp the base of the tube at the point of entry into the thorax, and push the tube into the thorax, in between rib spaces. Take care to avoid pushing the tube and trocar in too far, to avoid iatrogenic puncture of lung, heart or large vessels. An alternative to trocarized thoracic drain placement is to place a red rubber catheter. To place a red rubber catheter, make a small nick incision in the skin, then gently dissect through the subcutaneous tissues and intercostal muscles with the tips of a hemostat or Metzenbaum scissors. Once the pleural space is visible,



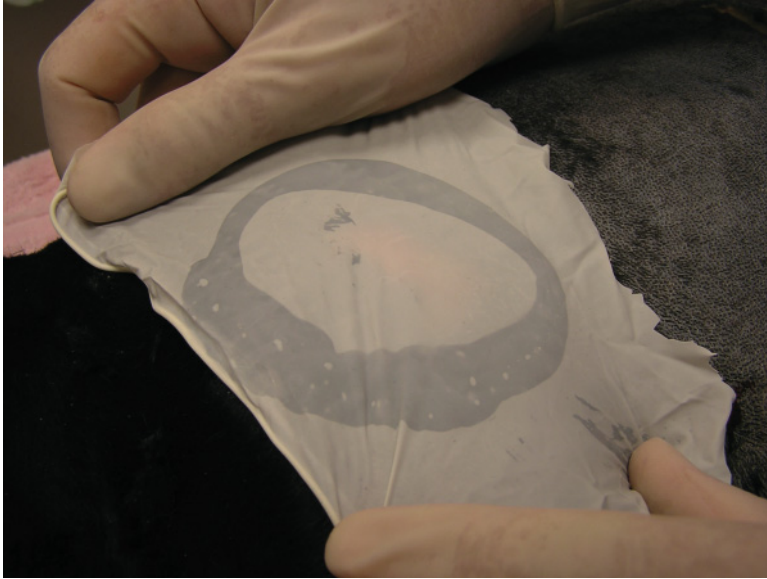
■ **Figure 77.5** Thoracostomy tube tunneled under the skin on the lateral thoracic wall, and being brought perpendicular to the thoracic wall before grasping it at its base, and inserting it into the thorax.



■ **Figure 77.6** Sterile lubricant around an open sucking chest wound.

grasp the tip of the red rubber catheter and push it into the thorax in between the 8th to 10th intercostal space. Push the catheter cranially to the level of the 5th intercostal space. To make the tube more rigid during this process, insert a rigid polypropylene urinary catheter through the red rubber catheter. The polypropylene catheter can be removed, and then the tip of the tube connected to a Christmas tree adapter, length of intravenous extension tubing, three-way stopcock, and a syringe or continuous suction apparatus. The tube can then be secured with a combination of horizontal mattress and finger-trap sutures. The tube should be covered with a sterile wrap, and checked daily for signs of erythema and infection.

- **Open sucking chest wounds:** If an animal has an open sucking chest wound, clip the wound, and place sterile lubricant or antibacterial gel around the wound (Figure 77.6). Next, place a sterile surgical glove over the wound (Figure 77.7). The combination creates a seal from the atmosphere and the pleural space. The pleural space can now be evacuated using a combination of thoracocentesis and thoracostomy tube placement.
- **Heimlich valves** are one-way valves that allow air to escape from the thoracic cavity during inhalation. Heimlich valves can be useful in patients greater than 20 kilograms, who have enough strength to open the valve. The Heimlich valves are not useful in smaller patients. Also, the apparatus can often become clogged with fibrin and not work properly. For this reason, their use is not recommended.
- **Analgesia** can be provided as systemic analgesia with opioids, as well as thoracic analgesia using 1 mg/kg lidocaine, and 1 mg/kg bupivacaine through the chest tube every 8 hours.



■ **Figure 77.7** Placement of a sterile glove over the thoracic wound and sterile lubricant, creating a seal between the atmosphere and pleural space.

- Tension pneumothorax may require creating a rapid hole in the thoracic wall and allow gas to escape. The defect can be closed once a thoracic tube has been placed and the tension pneumothorax is under control.
- Traumatic pneumothorax rarely requires surgical intervention.
- Spontaneous pneumothorax often requires surgical removal of the diseased lung. In the cases of bullae or blebs, however, rarely are the lesions isolated to one area, and recurrence is common. For this reason, surgical intervention should not be performed without a preoperative CT scan to determine the extent of pulmonary parenchymal involvement.

Activity

- Restrict activity to short walks, only on a leash, for as long as the chest tube is required, and at minimum, at least 1 week after tube removal, to allow healing of pulmonary lesions.

Surgical Considerations

- When performing anesthesia on any patient with traumatic pneumothorax or pulmonary contusions, use care to avoid overexpansion of the lungs to more than 20 cm H₂O, to avoid barotrauma and iatrogenic pneumothorax. Carefully inflate the cuff on endotracheal tubes, particularly in feline patients. When an animal needs to be rotated while under anesthesia, take care to disconnect the endotracheal tube from

the anesthetic circuit when turning the patient, to avoid twisting and placing torque on the endotracheal tube and trachea, and causing an iatrogenic tear.

- Thoracoscopy may allow visualization of blebs and bullae in cases of spontaneous pneumothorax.
- Bronchoscopy rarely identifies the location of the tracheal tear because it is often dorsal under the trachealis membrane.
- Lung lobectomy may be required to remove lesions that are leaking air.

Nursing Care

- Oxygen therapy 50 to 150 ml/kg per minute of humidified oxygen
- Analgesia
- Maintenance of the thoracic drainage tube to ensure that all connections are tightly sealed and not allowing air to enter the thorax. Check the tube manually several times a day that it is maintaining negative pressure if it is attached to a continuous suction device. Check the entrance site at least once daily for signs of infection.
- Keep an Elizabethan collar on at all times to prevent the patient from licking at the tube or removing the tube.



COMMENTS

Patient Monitoring

- Careful monitoring of respiratory rate and effort, thoracic auscultation, and arterial blood gases or pulse oximetry to evaluate the patient's response to therapy.
- Rapid, shallow, restrictive respiratory pattern should signal the recurrence of pneumothorax.
- Thoracic radiographs can be performed to evaluate for the recurrence or resorption of free air.
- Quantitation of air can be performed by using a syringe and measuring the amount of air aspirated. If an animal is attached to a closed collection system, monitor the bubbles in the water trap that are visible as air is sucked into it.

Prevention/Avoidance

- Do not allow animals to free roam or have access to large animals that can cause bodily harm.

Possible Complications

- Possible complications range from (most serious) death due to cardiovascular and respiratory collapse in the most severe cases, to iatrogenic lung laceration during thoracocentesis or thoracostomy tube placement. Infection, lung laceration, liver or diaphragm laceration, and reexpansion pulmonary edema can also potentially occur.

Expected Course and Prognosis

- The prognosis for traumatic pneumothorax is generally good and largely depends on the extent of other concurrent injuries. With simultaneous injuries such as internal hemorrhage, pulmonary contusions, and cardiovascular collapse, prognosis worsens. With spontaneous pneumothorax, the prognosis is more guarded, unless the location of the air leak is isolated to a small area of lung. With multifocal or generalized pulmonary parenchymal disease, prognosis becomes more and more guarded for long-term recovery.

Abbreviations

- CBC: complete blood count
- CT: computed tomography
- H₂O: water
- SpO₂: pulse oximeter oxygen saturation

Suggested References

- Brockman, DJ, and Puerto, DA. Pneumomediastinum and pneumothorax. In: King, LG, ed. *Textbook of respiratory diseases in dogs and cats*, pp. 616–624. St. Louis: Saunders, 2004.
- Maritato, KC, Colon, JA, and Kergosien, DH. Pneumothorax. *Comp Cont Educ Pract Vet* 2009;31(5):232–241.
- Slensky, K. Thoracic trauma. In: Silverstein, DC, and Hopper, K, eds. *Small animal critical care medicine*, pp. 662–667. St. Louis: Saunders-Elsevier, 2009.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Kate Hopper

Potassium Disorders—Hyperkalemia



DEFINITION/OVERVIEW

- Hyperkalemia is a serum electrolyte disorder that occurs when serum potassium concentrations exceed 5.5 mEq/L. The increased serum potassium level causes a depolarized state at the muscular cell membrane and causes skeletal and cardiac muscle dysfunction.



ETIOLOGY/PATHOPHYSIOLOGY

Systems Affected

Muscular

- Weakness

Cardiovascular

- Excitation and conduction abnormalities, dysrhythmias
- Translocation of potassium from intracellular to extracellular space caused by metabolic acidosis, rhabdomyolysis, massive tissue injury, drugs such as trimethoprim-sulfa and ACE-inhibitors, insulin deficiency (i.e., diabetes mellitus/diabetic ketoacidosis), hypertonicity, and hyperkalemic periodic paralysis
- Iatrogenic excess potassium administration in improperly mixed parenteral fluids after addition of potassium, failure to close the infusion port to the patient when potassium is added to the fluids, too rapid intravenous administration of potassium containing fluids, too rapid injection of potassium penicillin

Renal

- Urinary outflow obstruction or renal failure

Drugs

- Potassium-sparing diuretics

Metabolic

- Aldosterone deficiency

- Pseudohyperkalemia
 - Escape of potassium in red blood cells to the serum or plasma
 - This latter condition has no effect on the patient.
 - Occurs in Akitas



SIGNALMENT/HISTORY

- Can affect any age or breed
- History of muscular weakness and signs due to underlying disease such as renal failure or hypoadrenal function

Risk Factors/Causes

- Acute renal failure
- Postrenal obstruction
- Metabolic acidosis
- Hypoadrenocorticism
- Errors in parenteral fluid supplementation
- Certain drugs

Historical Findings

- Progressive appetite depression
- Lethargy
- Often vomiting from an underlying problem such as uremia
- Skeletal muscle weakness



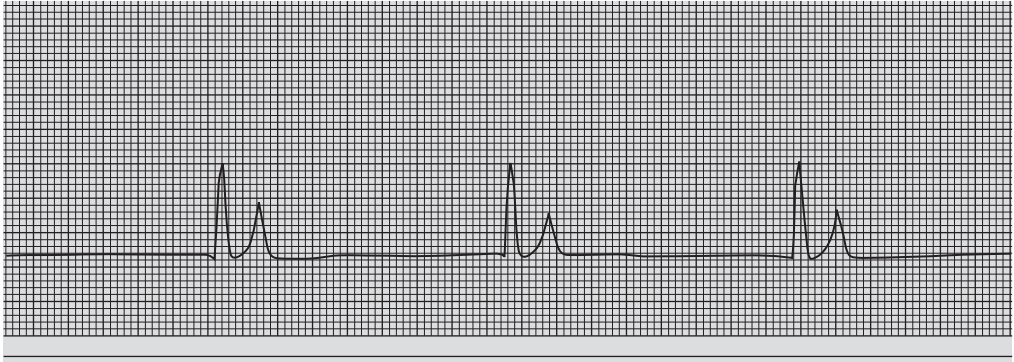
CLINICAL FEATURES

Dogs

- Muscles—Weakness
- Cardiac—Conduction and rhythm disturbances including tall or deep T waves, shortened P waves, prolonged PR interval, bradycardia, atrial standstill, sine waves, asystole (Figure 78.1)
- Other signs such as dehydration, weak pulses, prolonged capillary refill time, vomiting, sometimes diarrhea, mental depression; if due to renal failure, urinary obstruction, acute hypoadrenocortical crisis

Cats

- Muscles—Weakness
- Cardiac—Conduction and rhythm disturbances including tall or deep T waves, shortened B waves, prolonged PR interval, bradycardia, atrial standstill, sine waves, aberrant atrioventricular conduction, asystole



■ **Figure 78.1** Atrial standstill secondary to hyperkalemia in a blocked cat.

- Other signs such as dehydration, weak pulses, prolonged capillary refill time, vomiting, sometimes diarrhea, mental depression; if due to renal failure, urinary obstruction, acute hypoadrenocortical crisis



DIFFERENTIAL DIAGNOSIS

Dogs

- Renal failure
- Hypoadrenocorticism intoxications
- Hypermagnesemia
- Hypoaldosteronism
- Drugs inhibiting potassium excretion
- Hyperkalemia periodic paralysis

Cats

- Renal failure
- Hypoadrenocorticism intoxications
- Hypermagnesemia
- Hypoaldosteronism
- Drugs inhibiting potassium excretion



DIAGNOSTICS

- Serum magnesium concentration
- Serum potassium concentration
- Serum sodium concentration
- Electrocardiogram
- ACTH stimulation: to diagnose hypoadrenocorticism

- BUN, creatinine, urinalysis
- Abdominal ultrasound and other forms of imaging

Pathological Findings

- None associated with hyperkalemia itself.
- Hypoadrenocorticism—small adrenal glands grossly. Histopathology will show adrenocortical atrophy with a varying degree of fibrous tissue, lymphocytes, and plasma cell infiltrates. Rarely other pathology from other diseases can occur.
- Renal disease—varying types of renal pathology and histopathology depending on the cause.



THERAPEUTICS

- Treat underlying disease, lower serum potassium level.

Drug(s) of Choice

- Hypoadrenocorticism—provide intravenous 0.9% saline for rehydration and fluid maintenance.
- Prednisolone 5 to 10 mg/kg IV to provide glucocorticoid replacement in acute crisis.
- Desoxycorticosterone pivalate 2 mg/kg IM every 21 to 28 days to replace mineralocorticoid can be given SQ subsequently.
- Abnormal cardiac function calls for additional treatment measures:
 - Calcium gluconate 10%, 1 ml/kg IV, will counter cardiomyotoxicity.
 - Insulin—glucose—give regular insulin at one-fourth to one-half unit per kg with 2 grams of dextrose for each unit of insulin given. This will move potassium ions from the extracellular into the intracellular space.
- For renal disease, treatment consists of intravenous fluids and the same emergency measures (except for the steroids) mentioned previously for treating hyperkalemia associated cardiac abnormalities.

Precautions/Interactions

- Calcium gluconate and sodium bicarbonate should be administered in separate syringes to avoid precipitation which occurs when they are mixed.

Diet

- Diet usually unaffected with hypoadrenocorticism.
- With renal disease, a high biological value protein should be used once the animal resumes eating.

Activity

- Normal when the pet returns home

Surgical Considerations

- Resolve the hyperkalemia before surgery in order to avoid cardiac complications.

Alternate Procedure

- Peritoneal dialysis



COMMENTS

Client Education

- For renal patient, appropriate diet, water free choice, periodic evaluations by veterinarian.
- For hypoadrenal patient, be aware of early signs of decompensation: loss of appetite, weakness, and loss of vigor. Owners must provide maintenance medications lifelong and have periodic veterinary re-evaluations.

Patient Monitoring

- For hypoadrenocorticism, periodic serum sodium and potassium determinations with mineralocorticoid drug adjustments as necessary.
- For renal disease, BUN, creatinine, sodium, potassium, phosphorus, calcium, and urinalysis.

Prevention/Avoidance

- Diligent observing for signs of decompensation.
- Medication compliance.

Possible Complications

- Hyperkalemia can kill if not detected and treated in a timely manner.

Expected Course and Prognosis

- Hypoadrenocorticism: excellent prognosis with treatment compliance.
- Renal disease: fair to grave prognosis depending on pathology.

Synonyms

- Hyper K⁺
- ↑ K⁺

Abbreviations

- ACE: angiotensin-converting enzyme
- ACTH: adrenocorticotrophic hormone

- BUN: blood urea nitrogen
- IM: intramuscularly
- IV: intravenously
- SQ: subcutaneously

See Also

- Acute Renal Failure

Suggested Reading

- DiBartola, SP, and de Morais, HA. Disorders of potassium: hypokalemia and hyperkalemia. In: DiBartola, SP, ed. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed., 91–121. Philadelphia: Elsevier, 2006.
- Diereks, DB, Shumaik, GM, Harrigan, RA, et al. Electrocardiographic manifestations; electrolyte abnormalities. *J Emer Med* 2004;27(2):153–160.
- Londner, M, Hammer, D, and Kelen, GD. Fluid and electrolyte problems. In: Tintinalli, JE, Kelen, GD, Stapczynski, JS, eds. *Emergency Medicine—A Comprehensive Study Guide*, 6th ed., pp. 167–178. New York: McGraw-Hill, 2004.
- Phillips, SL, and Polzin, DJ. Clinical disorders of potassium homeostasis: hyperkalemia and hypokalemia. *Med Clin N Am Sm Anim Pract* 1998;28(3):545–564.
- Schaer, M. Hyperkalemia and hypernatremia. In: Ettinger, ST, ed. *Textbook of Veterinary Internal Medicine*, 4th ed., 46–29. Philadelphia: WB Saunders, 1994.

Author: Michael Schaer

Potassium Disorders— Hypokalemia



DEFINITION/OVERVIEW

- Hypokalemia is a serum electrolyte disorder that occurs when the serum potassium (K^+) is less than 3.5 mEq/L (normal range is 3.5 to 5.5 mEq/L).
- Occurs secondary to disorders of internal and/or external balance.



ETIOLOGY/PATHOPHYSIOLOGY

- Disorders of internal balance will translocate K^+ from the extracellular space (ECF) to the intracellular space (ICF).
- Includes: metabolic alkalosis, insulin administration, increased levels of catecholamines, beta-adrenergic agonist treatment or intoxication, and refeeding syndrome.
- Disorders of external balance are characterized by depletion.
- Includes: renal potassium wasting (common in cats), inadequate intake, diuretic drugs, osmotic and post-obstructive diuresis, inadequate parenteral fluid supplementation (iatrogenic), aldosterone-secreting tumor, vomiting and diarrhea, diabetic ketoacidosis, and renal tubular acidosis.
- Most of the clinical signs are a result of impaired membrane sodium-potassium pump function and a sustained hyperpolarized cell membrane. This delays calcium ion influx into the cell which causes impaired organ function.

Systems Affected

- Cardiovascular—hyperpolarization with complex conduction abnormalities and impaired blood pressure control causing hypertension.
- Endocrine/metabolic—glucose intolerance
- Gastrointestinal—ileus
- Musculoskeletal—weakness
- Renal—impaired tubular function (cats)
- Respiratory—impaired ventilation from muscle weakness



SIGNALMENT/HISTORY

- Renal tubular acidosis can be familial.

- History usually provides clues to the underlying problem such as predisposing medical problems and current medications.
- The most common clinical sign is muscle weakness.

Risk Factors

- Diabetes mellitus, body fluid losses, metabolic alkalosis, diuretic drugs, aldosteronoma, renal disease (cats).

Historical Findings

- Weakness
- Lethargy
- Mental depression
- Polydipsia/polyuria
- Sometimes vomiting—depending on cause



CLINICAL FEATURES

Dogs

- Muscle weakness
- Hypoventilation in extreme cases ($K^+ < 2.0 \text{ mEq/L}$)
- Gastrointestinal ileus

Cats

- Muscle weakness (Figures 79.1a and b)
- Hypoventilation
- Gastrointestinal ileus
- Impaired renal function
- Ventral cervical flexion from skeletal muscle weakness can occur in dogs and cats.



DIFFERENTIAL DIAGNOSIS

Dogs and Cats

- Hyperkalemia
- Hypo- and hypercalcemia
- Hypomagnesemia
- Peripheral neuropathy
- Combined neuromuscular disorders (myasthenia gravis)
- Organophosphate intoxication
- Myopathy



(a)



(b)

■ **Figure 79.1** a,b. This diabetic cat has severe skeletal muscle weakness because of hypokalemic myopathy. Note the characteristic ventral cervical posture. Recovery was uneventful after it received parenteral fluids supplemented with potassium chloride.



DIAGNOSTICS

- History of underlying diseases, diet, and pattern of weakness all helpful.
- Serum potassium concentration is absolute and confirmative.
- Serum creatine kinase value might be elevated, and this may or may not represent necrosis.
- Abdominal ultrasound when searching for hyperaldosteronism.
- Serum aldosterone concentrations when searching for hyperaldosteronism.
- Antiacetylcholinesterase receptor antibodies.

Pathological Findings

- Rarely muscle necrosis
- Ileus



THERAPEUTICS

- Correct the cause
- Replace potassium

Drug(s) of Choice

- Replace potassium deficits with potassium chloride solution intravenously or potassium gluconate powder orally mixed in food.
- Replacement deficits can be corrected with potassium chloride 10% solution given in amounts that are proportional to the severity of the hypokalemia—as shown in the following table which provides two different methods (a and b) for providing the potassium ions.

TABLE 79.1

| Serum Potassium Concentration | (a) mEq KCl Added to Liter of Saline | (b) mEq KCl Per Kg Body Weight Given Over 24 Hrs* |
|-------------------------------|---|--|
| 3.0–3.5 | 30 | 1–3 |
| 2.5–3.0 | 40–50 | 3–5 |
| 2.0–2.5 | 60 | 5–7 |
| <2.0 | 80 | 7–10 |

- The intravenous rate of administration for mild to moderate hypokalemia should usually not exceed 0.5 mEq/kg/hr, but for life-threatening hypokalemia (serum level <1.5 mEq/L) the rate can be increased to 1.5 mEq/kg/hr along with simultaneous ECG monitoring.

- Oral potassium gluconate is given as a powder added to food at a dose of ¼ teaspoonful (2 mEq) per 4.5 kg body weight twice daily.
- Potassium phosphate can be given if the patient is also markedly hypophosphatemic. One-half of the potassium replacement can be given intravenously at a dosage of 0.01–0.03 mmol/kg/hr over 6 hours.

Precautions/Interactions

- Rapid administration of potassium salts intravenously can cause cardiac dysrhythmia, conduction defects and death.
- Excessive potassium phosphate can cause hypocalcemia.

Alternative Drugs

- Potassium sparing diuretics such as spironolactone might be indicated. The dose for dogs is 2–4 mg/kg once daily and for the cat is 1.0 mg/kg twice daily.
- Mild hypokalemia can sometimes be corrected with foods high in potassium concentration such as bananas.

Diet

- Diet should be balanced and contain adequate amounts of potassium.

Activity

- The muscle weakness will limit the patient's activity.
- Strength will return soon after a few days of eukalemia.
- Return to exercise should be gradual over several days.

Surgical Considerations

- Hypokalemic animals are an anesthetic risk because of the potential for cardiac dysrhythmias, especially at serum concentrations of <3.0 mEq/L.
- Any underlying metabolic alkalosis in addition to the hypokalemia should be corrected prior to surgery, if possible.



COMMENTS

Client Education

- Any necessary dietary adjustments should be followed.
- Any need for continued potassium supplementation should be delivered.

Patient Monitoring

- Frequency will depend on underlying cause and the correction of the underlying problem.

Prevention/Avoidance

- All intravenous fluids that do not contain potassium should be supplemented so long as the patient is tolerant to this cation (i.e. acute renal failure or acute hypoadrenocorticism).
- Patients on potassium losing diuretics should have ample amounts of potassium in their diets.

Possible Complications

- Accidental overload of potassium salts during replacement treatment
- Cardiac arrhythmias if hypokalemia persists

Expected Course and Prognosis

- All signs are reversible.
- Underlying cause must be treated as well.
- Prognosis is good to excellent.

Synonyms

- None

Abbreviations

- Hypo K⁺
- ↓K⁺

See Also

- Hyperaldosteronism

Suggested Reading

1. Riordan LL, Schaer M. Potassium disorders. In: Silverstein D and Hopper K, eds. *Saunders Manual of Critical Care Medicine for Dogs and Cats*, 1st ed. St. Louis: Elsevier Inc, 2007.
2. DiBartola SP, deMorias HA. Disorders of potassium: hypokalemia and hyperkalemia. In: DiBartola SP, ed. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed. Philadelphia: Saunders Elsevier, 2006, pp 91–121.
3. Theisen SK, DiBartola SP, Radin J, et al. Muscle potassium content and potassium gluconate supplementation in normokalemic cats with naturally occurring chronic renal failure. *J Vet Intern Med* 1997;11:212.
4. Krisna GG, Steigerwalt SP, Pikus R, et al. Hypokalemic states. In: Narins RG, ed. *Maxwell and Kleeman's Clinical Disorders of Fluid and Electrolyte Metabolism*, 5th ed. New York: McGraw-Hill Inc, 1994, pp 659–696.
5. Gennari FJ. Hypokalemia. *N Engl J Med* 1998;339(7):451–458.

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Proptosis



DEFINITION/OVERVIEW

- Proptosis of the globe occurs when there is acute trauma that results in forward displacement of the globe such that when the extraocular and eyelid muscles contract in response to the displacement, the globe is prevented from returning to its normal position in large part by the abnormal eyelid position and the retrobulbar hemorrhage and edema (Figure 80.1).
- Proptosis is usually a unilateral occurrence, but bilateral traumatic proptosis can occur.
- Proptosis often leads to blindness in the affected eye. Secondary bradycardia may occur via the oculocardiac reflex.



■ **Figure 80.1** Severe proptosis in a Boston terrier. This eye is not salvageable and will be enucleated.



ETIOLOGY/PATHOPHYSIOLOGY

- Proptosis usually occurs due to a traumatic event. Often it occurs to a new dog being introduced to a new home and often over food or when the established dog exerts him or herself in defining certain boundaries to the new dog.
- It can also occur when a collar around the neck is pulled quickly or suddenly.
- Grooming nooses have also been involved in cases of proptosis in certain dogs.
- Scruffing the fur at the back of the neck can also result in proptosis in predisposed breeds.

Systems Affected

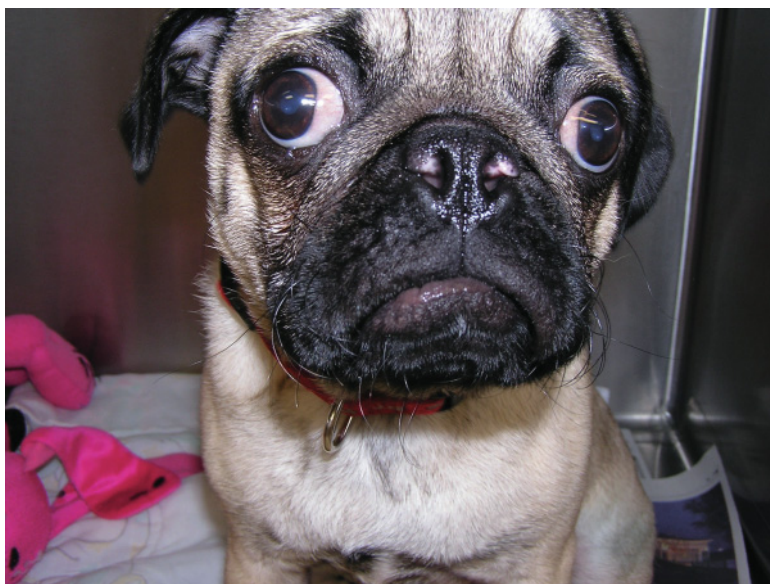
Ophthalmic

- Blindness due to optic nerve inflammation, severing, or atrophy, or severe hyphema
- Lagophthalmos
- Lateral strabismus
- Keratoconjunctivitis sicca



SIGNALMENT/HISTORY

- No age or sex predilection for this condition.
- Brachycephalic breeds are more prone to proptosis than mesocephalic and dolichocephalic breeds (Figure 80.2).



■ **Figure 80.2** Pugs are just one brachycephalic breed that are predisposed to proptosis.

- Brachycephalic breeds tend to have a much shallower orbit and a wider palpebral fissure.

Historical Findings

- Dog or cat cannot close the eye.
- Severe redness and swelling all the way around the eye.
- The eye has “popped” out.



CLINICAL FEATURES

Dogs and Cats

- Forward displacement of the globe
- Mild to severe chemosis
- Mild to severe subconjunctival hemorrhage (see Figure 80.2)
- Possible hyphema
- Possible anisocoria



DIFFERENTIAL DIAGNOSIS

Dogs and Cats

- Moderate to severe exophthalmos due to trauma, cellulitis, abscess, or mass.
- The position of the lids differentiates proptosis from exophthalmos. If the lid margins can be easily seen and identified, and they are not rolled inward, then the eye is exophthalmic and not proptosed.
- Sometimes severe exophthalmos and proptosis are treated similarly in order to take care of the globe and the ocular surface.



DIAGNOSTICS

- CBC, serum chemistry profile, urinalysis are usually normal unless the patient has sustained more physical trauma than to just the eye.
- Skull radiographs may be useful if orbital fractures are suspected.



THERAPEUTICS

- Keep cornea lubricated.
- Perform physical examination before anesthetizing patient to reposition the globe.
- Treat the patient for shock or head trauma, if necessary, before performing surgery.



■ **Figure 80.3** Preplaced sutures during repositioning of the proptosed globe. This eye is filled with blood, and the likelihood of restoring vision is poor. Another treatment choice in the patient would be enucleation.

Repositioning the Globe

- This should be done as soon as possible, as long as the patient is stable.
- This may be done using sedation and local anesthesia if necessary but is likely more efficiently done using general anesthesia, as long as the patient is stable.
- Pre-place two to three temporary tarsorrhaphy horizontal mattress sutures using a nonabsorbable 4-0 or 5-0 suture (Figure 80.3). The suture should enter or exit the eyelid margin at the level of the meibomian glands and not the conjunctival surface of the eyelid. Splitting the thickness of the eyelid like this will most likely keep the suture material from making contact with the cornea and causing an ulcer. If it is too difficult to pass the needle precisely through the eyelid margin with the globe proptosed, the sutures may be passed full thickness through the lid to reposition the globe. Once repositioned, the sutures are replaced with appropriately positioned tarsorrhaphy sutures.
- Lateral canthotomy may relieve some of the eyelid tension and aid in preplacement of the sutures.
- Apply an appropriate antibiotic ophthalmic ointment (i.e., neomycin, polymyxin B, bacitracin) to the cornea.
- Using a scalpel handle over the cornea but under the preplaced sutures, the globe is held in place while gentle traction is placed on the all sutures simultaneously, bringing the eyelids forward and in proper position over the globe.
- Tarsorrhaphy sutures are tied or replaced. Additional sutures are placed if necessary. The lateral canthotomy is closed. Usually the medial canthus is open a few millimeters so ophthalmic medications may be applied.

Enucleation of the Globe

- Should be considered if:
 - The owner is unable to make follow-up appointments and take care of the eye if further care is necessary after replacement of globe.
 - The eye has ruptured.
 - Three or more extraocular muscles have been torn.
 - The eye is completely filled with blood.

Drug(s) of Choice

- Systemic antibiotics should be used at least 7 to 14 days.
- Topical antibiotics should be used as long as sutures are in place. Frequency and type of topical antibiotic will depend on degree of corneal or scleral trauma.
- Systemic anti-inflammatory steroidal should be used, if the patient can tolerate it.
- Nonsteroidal anti-inflammatories are effective as well if corticosteroids cannot be used.
- Topical corticosteroids may be used if cornea is not significantly damaged and if uveitis or hyphema are significant.
- Topical atropine relieves ciliary body muscle spasm and dilates the pupil to try and prevent posterior synechiae formation.

Precautions/Interactions

- Do *not* use topical corticosteroids if the cornea is unhealthy.
- Do *not* use systemic corticosteroids if intraocular or retrobulbar infection is likely.
- Secondary bradycardia may occur via the oculocardiac reflex when manipulating the globe. Have atropine ready if necessary, although premedication with glycopyrrolate can help prevent bradycardia secondary to repositioning of the globe.

Activity

- Walks using a leash and harness should be fine until the eye has healed. Keep the animal indoors or in a well-controlled environment until healing is complete.



COMMENTS

Client Education

- The patient should be kept quiet and the area around the eye clean while it is healing.
- Keep other animals from licking the affected eye.
- An Elizabethan collar may be necessary to protect the eye, and is recommended.
- Administer ophthalmic solutions or suspensions before applying ophthalmic ointments.

Patient Monitoring

- Monitor for excessive discharge from eye, and for excessive swelling, heat, or pain when opening mouth or eating, which may indicate orbital abscess formation.
- First recheck examination should be 5 to 7 days after repositioning the globe. Much of the retrobulbar hemorrhage and swelling may be reduced and significant suture loosening may occur at this time. This recheck is to make sure suture placement is still acceptable and not causing problems for the corneal surface.
- Sutures are usually removed sequentially and not all at the same time, starting at 10 to 14 days after repositioning. The last suture may not be removed until 3 to 4 weeks after placement or longer, if appropriate eyelid function has not returned, and there is still risk of drying out or injury to the ocular surface due to exposure.

Prevention/Avoidance

- This injury is usually accidental and very sudden. Be careful introducing brachycephalic dogs to large dogs.

Possible Complications

- Lateral or dorsolateral strabismus due to extraocular muscle avulsion. May improve or worsen with time.
- Keratoconjunctivitis sicca.
- Neurotrophic keratitis.

Expected Course and Prognosis

- If the globe can be successfully replaced, and severe hyphema is not present, then there is a chance some vision may be preserved.
- Prognosis for vision is usually poor, regardless of how quickly the globe is repositioned.
- Prognosis is usually fair to good for being able to save the globe.
- Positive menace response, direct pupillary light reflex in injured eye and a consensual pupillary light reflex in normal eye; better prognosis for maintaining vision, but still guarded because damage to the eye may still be occurring.
- Pupil size or response not necessarily an accurate indicator of visual outcome.

Abbreviations

- CBC: complete blood count

Suggested Reading

Gelatt, KN, and Gelatt, JP. *Small Animal Ophthalmic Surgery: Practical Techniques for the Veterinarian*. Edinburgh: Butterworth and Heinemann, 2001.

Miller, PE. Ocular emergencies. In: Maggs, DJ, Miller, PE, and Ofri, R, eds. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed., pp. 562–570. St. Louis: Saunders, 2008.

Severin, GA. *Severin's Veterinary Ophthalmology Notes*. 3rd ed. Fort Collins, CO: DesignPointe Communications Inc., 1996.

Author: Bradley P. Graham

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Stephanie L. Smedes

Pulmonary Thromboembolism (PTE)



DEFINITION/OVERVIEW

- Occlusion of the pulmonary arterial system with thrombi that may arise from distant sites
- Usually refers to thrombi, however, in some situations the term is also used for parasites, fat, or neoplastic cells
- PTE is a secondary phenomenon; evidence of a predisposing cause is beneficial in diagnosis and therapy.
- Prevalence in cats estimated at 0.06 percent; bimodal distribution with maximum at 0 to 2 and 10 to 12 years of age
- Prevalence in dogs estimated at 0.9 percent



ETIOLOGY/PATHOPHYSIOLOGY

- Stasis of blood, endothelial damage, and hypercoagulability (collectively referred to as Virchow's triad) predisposes patient to the formation of a thrombus.
- Pulmonary vascular resistance increases due to mechanical obstruction of blood flow and vasoactive mediators released from the thrombus causing vasoconstriction of the vessels.
- PTE is considered a secondary condition.

Systems Affected

- Cardiovascular
 - Jugular distention/pulsation
 - Clinical signs of right-sided heart failure
 - Pleural effusion
 - Ascites
 - Acute large PTE may result in low output cardiac failure and shock.
- Respiratory
 - Sudden onset respiratory distress (58 to 96 percent of dogs, 55 percent of cats)
 - Tachypnea
 - Coughing with or without hemoptysis
 - Crackles or increased bronchial sounds

- Possibly normal lung sounds
- Abnormal gas exchange
- Altered ventilatory control
- Hypoxia due to ventilation/perfusion mismatch, increased alveolar dead space, and intrapulmonary or intracardiac right-to-left shunting
- Hypoxia can be made worse by edema due to overperfusion to nonthrombosed pulmonary tissue.



SIGNALMENT/HISTORY

- Middle-aged to older animals
- No sex or breed predilection

Risk Factors/Causes

- Reported primary causes in the dog include:
 - Immune-mediated diseases (like immune-mediated hemolytic anemia)
 - Neoplasia
 - Hyperadrenocorticism
 - Glomerular disease and other protein losing diseases
 - Amyloidosis
 - Recent surgery
 - Sepsis
 - Pancreatitis
 - Endogenous or exogenous corticosteroids
 - Vascular diseases like heartworm disease and vasculitis
 - Nephrotic syndrome
 - Iatrogenic causes such as indwelling catheters and transfusions
 - Hypothyroidism
 - Cardiac disease
 - Disseminated intravascular coagulopathy
 - Trauma
 - Uncommonly pulmonary fungal infections (blastomycosis)
- In cats concurrent diseases that may serve as primary cause include:
 - Neoplasia
 - Pancreatitis
 - Nonhemolytic anemia
 - Hepatic lipidosis
 - Feline infectious peritonitis
 - Dilated cardiomyopathy
 - Glomerulonephritis
 - Bacterial pneumonia
 - Encephalitis
 - Concurrent disease is not always present.

Historical Findings

- Reported historical complaints include:
 - Vomiting
 - Melena
 - Fever
 - Labored breathing
 - Lethargy
 - Altered mental state
- Some of these historical complaints are likely related to primary diseases that predispose to PTE.



CLINICAL FEATURES

- Labored breathing or tachypnea
- Tachycardia
- Fever
- Restlessness
- Weakness
- Increased bronchial lung sounds and potential for crackles
- Cardiac murmurs (especially right-sided murmurs)
- Hepatosplenomegaly



DIFFERENTIAL DIAGNOSIS

- Airway obstruction
- Acute pneumonia
- Acute respiratory distress syndrome
- Other pulmonary parenchymal diseases
- Other causes of pulmonary hypertension
- Acute congestive heart failure
- Noncardiogenic pulmonary edema
- Pleural space disease
- Asthma (bronchitis) in cats



DIAGNOSTICS

- Diagnosis is difficult because symptoms are not specific for PTE and there is not a definitive diagnostic test.
- Lack of clinical suspicion contributes to the difficulty in diagnosis.
- Presence of predisposing factors may be best indication to pursue diagnostics for PTE.

- Complete blood count
 - Changes most likely due to primary diseases that put patient at risk for PTE
 - Thrombocytopenia or thrombocytosis possible
- Blood chemistry analysis
 - Increased alkaline phosphatase
 - Increased alanine transaminase
 - Abnormal electrolyte values (i.e., hypokalemia, hyponatremia, and hypochloremia among most common)
 - Hypoalbuminemia
 - Azotemia
- Urinalysis
 - Changes most likely due to primary diseases that put patient at risk for PTE
 - Dilute urine specific gravity
 - Proteinuria
 - Potential pyuria or bacteriuria
- Coagulation profile FDPs: can be used to support diagnosis of disseminated intravascular coagulation
 - Elevated FDPs may be seen but are considered insensitive indicators of thromboembolism.
 - Prolongation of the PT or aPTT
- D-Dimers are degradation product of cross-linked fibrin and specific for active coagulation and fibrinolysis.
 - False-negatives are uncommon.
 - Positive results need to be taken with the clinical picture in mind.
 - Reported sensitivities and specificities at different levels include:
 - >500 ng/ml: 100 percent sensitive and 70 percent specific
 - >1000 ng/ml: 80 percent sensitive and 94 percent specific
 - >2000 ng/ml: 35 percent sensitive and 98.5 percent specific
- Plasma antithrombin levels may be low.
- Arterial blood gas
 - Hypoxemia primarily due to ventilation/perfusion mismatch but physiologic shunting and increased dead space can contribute
 - Hypocapnea
 - Metabolic acidosis
 - Increased alveolar-to-arterial gradient
 - Response to supplemental oxygen variable
- Thoracic radiography
 - Normal (10 to 30 percent of dogs and 14 percent of cats with PTE on postmortem)
 - Possibly hypovascular lung regions
 - Interstitial to alveolar lung infiltrates that do not correlate with the degree of respiratory distress
 - Enlarged pulmonary arteries (especially centrally) with vascular tapering and oligemia
 - Cardiomegaly and pleural effusion common in both dogs and cats

- Echocardiography
 - Potential to visualize thrombus if in proximal pulmonary arteries or right-sided heart
 - Poorly contracting right ventricle
 - Leftward shift of the septum during part of the cardiac cycle
 - Pulmonary artery dilation
 - High-velocity tricuspid regurgitation and pulmonic insufficiency jets
 - These can be used to estimate the pulmonary artery systolic and diastolic pulmonary arterial pressures respectively.
 - Pulmonary artery systolic pressure = $4 \times (\text{velocity of tricuspid regurgitation jet})^2 + \text{estimated right atrial pressure}$
 - Pulmonary artery diastolic pressure = $4 \times (\text{pulmonary insufficiency end-diastolic velocity})^2$
 - Diagnosis of pulmonary arterial hypertension is not analogous to PTE; it may increase index of suspicion when combined with other diagnostic tests.
- Pulmonary perfusion scintigraphy is accepted as safe and sensitive but only available at some referral institutions.
 - Involves intravenous injection of technetium labeled macroaggregated albumin
 - Perfusion deficits can also occur in nonventilated regions with reflex vasoconstriction.
- Ventilation/perfusion scan is a perfusion scan combined with a ventilation scan using technetium labeled radioaerosol.
 - Increases sensitivity
 - Uncommonly performed in veterinary medicine
 - Because it cannot differentiate all primary pulmonary parenchymal diseases from PTE it is frequently not definitive.
- Pulmonary angiography
 - Most sensitive and specific test but uncommonly performed due to need for general anesthesia in veterinary patients
 - Nonionic contrast should be used to minimize systemic hypotension
 - Patients with pulmonary hypertension are at increased risk of complications due to the procedure.
 - Diagnosis of PTE includes intraluminal filling defect in the pulmonary artery or abrupt vessel occlusion and visualization of the trailing edge of the thromboembolism.
- Spiral computed tomography and magnetic resonance imaging with angiography are commonly used in human medicine but the need for general anesthesia limits their use in veterinary medicine.

Pathologic Findings

- Pulmonary emboli visible
 - Pleural effusion
 - Concurrent pulmonary pathology
 - Bronchopneumonia
 - Pulmonary edema

- Pulmonary neoplasia
- Interstitial fibrosis
- Pulmonary calcification
- Emphysema
- Hyaline membrane disease
- Most common primary postmortem diagnoses included immune mediated hemolytic anemia, sepsis, and amyloidosis.
- Most dogs have multiple disease processes.



THERAPEUTICS

- If primary cause can be identified, treatment should be instituted.
- Symptomatic respiratory support
 - Supplemental oxygen
 - Positive end-expiratory pressure ventilation may be required.
- Anticoagulant therapy
 - Heparin: After baseline PT and aPTT and ACT initial intravenous dose of 100 to 300U/kg given followed by 100 to 300U/kg SQ or IV every 6 to 8 hours. The dose is adjusted to maintain the aPTT at one and a half to two times normal.
 - Low molecular weight heparin
 - More expensive than heparin but cost is theoretically balanced by not needing to evaluate coagulation times
 - Dalteparin dose (dog and cat): 100 to 150IU/kg SQ every 12 to 24 hours
 - Enoxaparin dose (dog and cat): 1 mg/kg SQ every 12 to 24 hours
- Warfarin
 - Coagulation times must be closely monitored and are more difficult to regulate.
 - Uncommonly used
 - If used, heparin must be administered during the initial hypercoagulable period (usually 5–7 days) due to warfarin effects on protein C.
 - Warfarin doses:
 - Dog: 0.1 to 0.2mg/kg PO every 24 hours
 - Cat: 0.1 to 0.2mg per cat PO every 24 hours
- Antiplatelet drugs (i.e., aspirin, clopidogrel, ticlodipine)
 - Used primarily for prevention in patients considered at high risk
 - Clopidogrel doses
 - Cat: 18.75 to 75 mg once daily in the cat
 - Dog: Doses in the dog have not been published to date.
 - Aspirin doses
 - Dog: 0.5 mg/kg PO every 12 to 24 hours
 - Cat: 5 to 81 mg PO every 72 hours

- Cautious use of parenteral fluids
 - Hypotension may be present because of pulmonary arterial obstruction and impedance to left heart filling and may be aided by fluids.
 - Aggressive fluid therapy can further increase right-sided heart filling, displacing the intraventricular septum to the left further impeding left-sided heart filling and compromising cardiac output.
- Thrombolytic therapy (rt-PA, streptokinase)
 - Not commonly used and reserved for early use
 - Excessive bleeding and not uncommonly fatal bleeding is possible.
 - rt-PA activates bound plasminogen making it more “clot specific”.
 - Dog rt-PA dose: 1 mg/kg IV every 60 minutes for a total of 10 doses
 - Cat rt-PA dose: 0.25 to 1 mg/kg per hour for a total dose of 1 to 10 mg/kg IV
 - Streptokinase is not fibrin dependent and therefore leads to a systemic lytic state.
 - Dog streptokinase dose: 90,000 IU loading dose over 30 minutes followed by CRI of 45,000 IU/hour for 7 to 12 hours
 - Alternatively a loading dose of 15,000 to 18,000 IU/kg can be used followed by same CRI protocol.
- Surgical thrombectomy could be considered but is rarely performed.



COMMENTS

Client Education

- Most client information provided will be related to primary disease.
- For patients on anticoagulant therapy, the owner should monitor for bruising or bleeding.

Patient Monitoring

- Monitor patients response to therapy (respiratory rate and effort and serial blood gas analysis).
- Monitor coagulation times (aPTT and PT) carefully.

Prevention/Avoidance

- Patients with a primary condition that makes them at increased risk for PTE can be placed on prophylactic anticoagulant therapy.

Possible Complications

- Use of thrombolytic agents or anticoagulants increase the patients chances of hemorrhage and should be monitored closely.

Expected Course and Prognosis

- Variable prognosis based on size of thrombus, underlying cause, and time course of clinical recognition and therapy
- Poor prognosis with large thrombus in central pulmonary artery

Abbreviations

- ACT: activated clotting time
- aPTT: activated partial thromboplastin time
- CBC: complete blood count
- CRI: constant rate infusion
- FDP: fibrin degradation products
- IV: intravenously
- PO: by mouth
- PT: prothrombin time
- rt-PA: recombinant tissue plasminogen activator
- SQ: subcutaneously

Suggested Reading

- Hawkins, EC. Pulmonary parenchymal diseases, hypertension, and pulmonary thromboembolism. In: Ettinger, SJ, and Feldman, EC, eds. *Textbook of Veterinary Internal Medicine: Diseases of the Dog and Cat*, 5th ed., pp. 1078–1081. St. Louis: Elsevier Saunders, 2000.
- Johnson, LR, Lappin, MR, and Baker, DC. Pulmonary thromboembolism in 29 dogs: 1985–1995. *J Vet Intern Med* 1999;13:338–345.
- Nelson, OL, and Andreasen, C. The utility of plasma D-dimers to identify thromboembolic disease in dogs. *J Vet Intern Med* 2003;17:830–834.
- Schermerhorn, T, Pembleton-Corbett, JR, and Kornreich, B. Pulmonary thromboembolism in cats. *J Vet Intern Med* 2004;18:533–535.

Author: Allison M. Heaney

Pulmonary Contusions



DEFINITION/OVERVIEW

- Syndrome that causes pulmonary parenchymal and alveolar damage secondary to compressive and decompressive forces associated with blunt trauma to the thorax.



ETIOLOGY/PATHOPHYSIOLOGY

- Compression then decompression of the thorax during blunt thoracic trauma transfers the energy or mechanical force to the pulmonary parenchyma and alveoli. The result is damage to the parenchyma and alveolar capillary membrane. Leakage of blood and plasma fluid into the alveoli and pulmonary interstitial space results in areas of lung with a ventilation/perfusion mismatch and hypoxia.
- Following initial injury, influx of fluid and inflammatory cells into the damaged area can perpetuate the pulmonary damage and injury by the generation of oxygen-derived free radical species and oxidative damage to the lung, and cause secondary lung injury. Depending on the extent of damage, ALI or ARDS can result.

Systems Affected

- Respiratory—areas of lung that are perfused but not ventilated well cause a ventilation/perfusion mismatch and hypoxia, tachypnea, orthopnea, restrictive respiratory pattern and hemoptysis may be present; can progress to ALI or ARDS
- Other body systems are affected secondary to hypoxia.

Incidence/Prevalence

- Reported in 34 to 57 percent of dogs and 18 percent of cats with limb fractures following motor vehicle trauma.
- Occurs in approximately 50 percent of animals with thoracic trauma.

Geographic Distribution

- Worldwide



SIGNALMENT/HISTORY

Species

- Dogs and cats

Historical Findings

- History of blunt trauma
- Free-roaming animal or on property with large animals
- Acute onset
- Respiratory difficulty

Physical Examination Findings

- Tachypnea
- Pale or cyanotic mucous membranes
- Orthopnea
- Cough
- Hemoptysis
- Increased bronchovesicular sounds and pulmonary crackles
- Often other physical examination indications of trauma
- Severity of respiratory signs associated with the degree of injury

Risk Factors/Causes

- Free-roaming off leash
- Fall from height
- Lives with larger animals or farm animals
- Potential for animal abuse injury
- Potential for coagulopathy



DIFFERENTIAL DIAGNOSIS

Differentiating Causes

Coagulopathy

- Hemothorax or pulmonary hemorrhage from vitamin K antagonist rodenticide intoxication
- Can be differentiated from pulmonary contusions by coagulation tests, as ACT and PTs will be markedly prolonged with vitamin K antagonism. Severe thrombocytopenia $<50,000$ platelet/ μL can be associated with pulmonary hemorrhage.

Neoplastic Cause of Pulmonary Hemorrhage

- Hemangiosarcoma most common

Pneumothorax

- Muffled lung sounds; will see retraction of the lungs away from the thoracic wall on thoracic radiographs

Diaphragmatic Hernia

- Loss of detail in pleural cavity, loss of demarcation of diaphragm, possible inclusion of abdominal contents in thorax
- Cardiac failure with pulmonary edema
- Inhaled or ingested toxins, such as paraquat
- Bacterial or viral pneumonia

**DIAGNOSTICS****Complete Blood Count/Biochemistry/Urinalysis**

- Not specific for pulmonary contusions, changes such as anemia, neutrophilic leukocytosis, or elevations in liver enzyme activities may be associated with trauma but not related to pulmonary contusion, per se.
- Urinalysis is usually normal unless damage to the kidneys or urinary bladder has occurred secondary to trauma.

Other Laboratory Tests

- PT or ACT to rule out vitamin K antagonist rodenticide toxicity
- Platelet count to rule out severe thrombocytopenia and secondary pulmonary hemorrhage

Diagnostic Procedures**Thoracic Imaging**

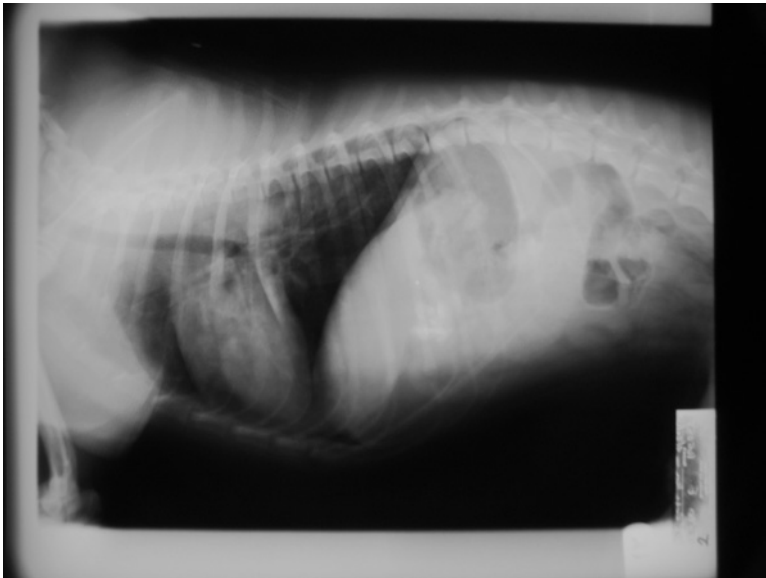
- Thoracic radiographs should be performed only *after* cardiovascular and pulmonary stabilization of the patient, whenever possible.
- Interstitial to alveolar lung pattern in any lung field (Figures 82.1 and 82.2)
- Radiographic appearance of pulmonary contusions may lag behind clinical signs and may appear within 24 to 48 hours of trauma
- Lack of radiographic appearance of contusions does not rule out their presence or potential to form after trauma.
- Severity is related to degree of injury.

**THERAPEUTICS****Drug(s) of Choice**

- Oxygen supplementation (50–150 ml/kg per minute)



■ **Figure 82.1** VD thoracic radiograph from a dog 12 hours after being hit by a car. Note the interstitial to alveolar pattern in the left cranial and left middle lung field.



■ **Figure 82.2** Lateral thoracic radiograph of the same dog. Note the alveolar pattern overlying the cardiac silhouette.

- The use of furosemide is controversial and not currently recommended because it could potentially worsen hypovolemic shock.

Contraindications

- Diuretic drugs such as furosemide have not been shown to be efficacious and can exacerbate hypovolemic shock.
- The use of NSAIDs in any traumatized patient is controversial and not recommended until the patient is normotensive and renal function has been proven to be normal.
- Antibiotics—Less than 5 percent of patients with traumatic pulmonary contusions develop respiratory infections secondary to injury. The use of empiric antibiotics in a patient with pulmonary contusions can promote the development of bacterial resistance, and is therefore, contraindicated.
- Overzealous crystalloid fluid therapy can be associated with worsening of pulmonary contusions; fluid therapy should be titrated according to patient's blood pressure and cardiovascular perfusion parameters.



COMMENTS

Patient Monitoring

- Monitor respiratory rate and effort, mucous membrane color, presence of hemoptysis, respiratory difficulty/orthopnea, respiratory sound on thoracic auscultation; serial measurements of blood pressure, pulse quality, pulse oximetry or arterial blood gas analysis. ECG to evaluate for traumatic myocarditis and cardiac dysrhythmias.

Prevention/Avoidance

- Avoid interactions with motor vehicles and large animals or fall from height.
- Leash restriction or run in enclosed area, away from traffic.

Possible Complications

- ARDS
- Bacterial pneumonia (extremely rare)

Expected Course and Prognosis

- Potential to worsen over first 24 hours post-injury
- Most patients will be able to be discharged within 36 hours of initial injury.
- Severe contusions may require assisted ventilation with positive end-expiratory pressure until wounds heal.
- Potential for development of ARDS and death in severe cases, risk increases with the degree of multitrauma.

Abbreviations

- ACT: activated clotting time
- ALI: acute lung injury
- ARDS: acute respiratory distress syndrome
- ECG: electrocardiogram
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PT: prothrombin time

Suggested Reading

Campbell, VL, and King, LG. Pulmonary function, ventilatory management and outcome of dogs with thoracic trauma and pulmonary contusions: 10 cases. (1994–1998). *J Am Vet Med Assoc* 2000;217:1505–1509.

Powell, LL, Rozanski, EA, Tidwell, AS, and Rush, JE. A retrospective analysis of pulmonary contusion secondary to motor vehicle accidents in 143 dogs: 1994–1997. *J Vet Emerg Crit Care* 1999;9:127–136.

Serrano, S, and Boag, AK. Pulmonary contusions and hemorrhage. In: Silverstein, C, and Hopper, K, eds., *Small Animal Critical Care Medicine*, pp. 105–110. St. Louis: Saunders Elsevier, 2009.

Sigrist, N, Doherr, MC, and Spreng, DE. Clinical findings and diagnostic value of posttraumatic thoracic radiographs in dogs and cats with blunt trauma. *J Vet Emerg Crit Care* 2004;14:259–268.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Lesley G King

Pulmonary Edema— Cardiogenic



DEFINITION/OVERVIEW

- Cardiogenic pulmonary edema is the accumulation of fluid in the pulmonary interstitial space and alveoli subsequent to left-sided cardiac dysfunction and elevations in pulmonary venous and pulmonary capillary pressures.



ETIOLOGY/PATHOPHYSIOLOGY

- Cardiogenic pulmonary edema may occur secondary to any heart condition that impairs function of the left side of the heart, including diseases that promote volume overload, systolic dysfunction, or diastolic dysfunction.
- With progressive cardiac dysfunction, left atrial, pulmonary venous and pulmonary capillary hydrostatic pressures increase.
- Pulmonary edema develops when the net movement of fluid, colloid, and solutes from the vasculature into the interstitial space exceeds its return to the circulation.
- Cardiogenic pulmonary edema impairs gas exchange and lung mechanics and may ultimately lead to death.
- Common congenital lesions that contribute to the development of pulmonary edema include:
 - Left-to-right shunting PDA
 - Left-to-right shunting ventricular septal defect
 - Mitral valve dysplasia
 - Subaortic stenosis (uncommonly)
- Common acquired conditions that contribute to the development of pulmonary edema include:
 - Chronic degenerative mitral valve disease (dogs)
 - Dilated cardiomyopathy (dogs)
 - Hypertrophic cardiomyopathy (cats)

Systems Affected

- Respiratory—Cardiogenic pulmonary edema impairs gas exchange and reduces lung compliance.

- Cardiovascular—While cardiac dysfunction often leads to the development of cardiogenic pulmonary edema the associated hypoxemia may contribute to arrhythmogenesis and further impair cardiac function.
- Musculoskeletal—Hypoxemia contributes to weakness.
- Nervous—Hypoxemia may contribute to depression and lethargy, or when combined with arrhythmias or activity contribute to syncope.
- Hepatobiliary—Concurrent right-sided congestion may contribute to cholestasis and ascites.



SIGNALMENT/HISTORY

- The signalment varies based on the cardiac disease that leads to the development of pulmonary edema.
 - Left-to-right shunting PDAs can be seen in any young dog but females and many small breed dogs, including Chihuahuas, Maltese, toy and miniature poodles, Pomeranians, Bichon Frise, Cavalier King Charles spaniels, and Shetland sheepdogs are reportedly overrepresented.
 - Chronic degenerative mitral valve disease is most common in middle-aged to older small breed dogs.
 - Dilated cardiomyopathy is more commonly identified in middle-aged to older large to giant breed dogs with boxers, Doberman pinschers, Great Danes, and Irish wolfhounds reportedly overrepresented.
 - Purebred cats including Maine coon cats and Ragdolls have identified genetic alterations that may contribute to hypertrophic cardiomyopathy although the disease is also commonly diagnosed in domestic shorthair and domestic longhair cats.
- Depending on the etiology and severity of the cardiac disease and the presence of risk factors, owners may report a slow, insidious onset of clinical signs or an acute, rapid-onset of life-threatening respiratory compromise.

Risk Factors/Causes

- Cardiac arrhythmias (e.g., development of atrial fibrillation or significant ventricular ectopy) may reduce cardiac performance and precipitate the development of pulmonary edema.
- General anesthesia and intravenous fluids in animals with otherwise compensated, yet severe cardiac disease may precipitate the development of pulmonary edema.
- Difficult to predict events, like rupture of chordae tendineae in dogs with mitral valve disease or systemic thromboembolization in cats; may be associated with the rapid development of cardiogenic pulmonary edema.

Historical Findings

- Coughing (dogs)

- Tachypnea, dyspnea, open-mouth breathing.
 - These signs may be exacerbated during recumbency.
- Exercise intolerance.
- Inappetence and weight loss.



CLINICAL FEATURES

Dogs

- Almost always have a cardiac murmur or gallop.
- Arrhythmias may be audible.
- Coughing, tachypnea, dyspnea, or orthopnea.
- There may be audible crackles and wheezes during pulmonary auscultation.
- Many dogs with cardiogenic pulmonary edema will be tachycardic.
- Severe edema may be accompanied by expectoration of pink foam or cyanosis.

Cats

- Often have a cardiac murmur or gallop.
- Arrhythmias may be audible.
- Tachypnea, dyspnea, open-mouth breathing.
- Crackles may be audible although some cats with pulmonary edema have concurrent pleural effusion, which diminishes lung sounds and may produce an audible fluid line.
- Some cats will present bradycardic and hypothermic.
- Some cats present with concurrent systemic thromboembolization.



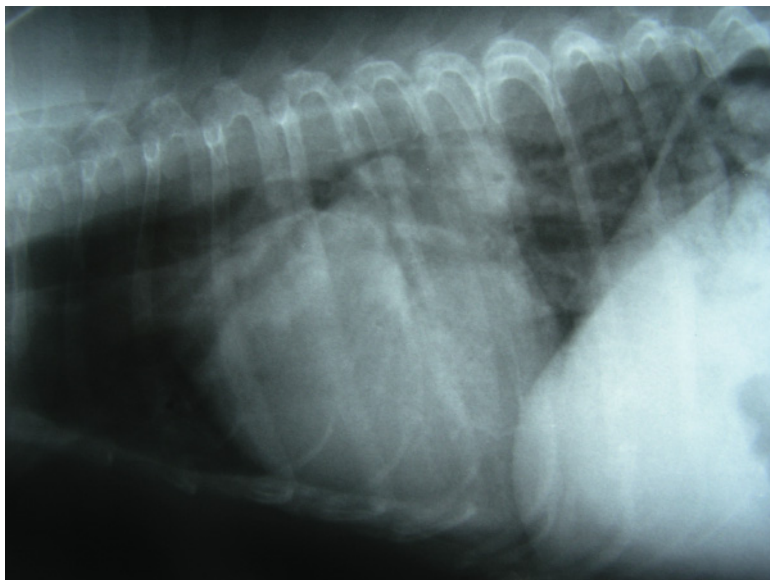
DIFFERENTIAL DIAGNOSIS

- Pneumonia
- Pulmonary thromboembolism and pulmonary hypertension
- Heartworm disease
- Tracheal collapse
- Feline asthma
- Obstructive lung disease
- Bronchitis
- Pulmonary fibrosis
- Neoplasia
- Noncardiogenic pulmonary edema
- Pulmonary contusions
- Inflammatory respiratory disease
- Many dogs and cats with these disorders have concurrent cardiac disease that could lead to a false assumption of cardiogenic pulmonary edema if treatment decisions are based only on the physical examination.



DIAGNOSTICS

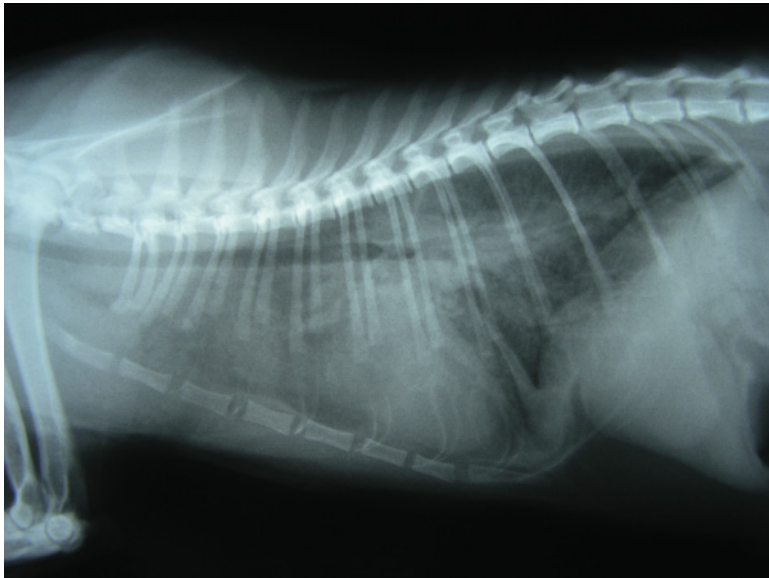
- Animals with cardiogenic pulmonary edema may be in extremely critical condition and the diagnostic tests performed must be dictated by the clinical situation.
- Thoracic radiographs
 - Common hallmarks of cardiogenic pulmonary edema in dogs include left atrial enlargement (Figure 83.1), pulmonary venous congestion, and perihilar interstitial edema.
 - As the pulmonary edema progresses and alveoli are flooded, it obscures the pulmonary vessels and produces air bronchograms, often in the perihilar region and right caudal lung lobe.
 - Severe, fulminant congestive heart failure may produce diffuse alveolar disease (Figure 83.2).
 - Instead of the classic pattern of cardiogenic pulmonary edema in dogs, cats tend to have left auricular enlargement on the ventrodorsal or dorsoventral view and their patterns of pulmonary edema tend to be patchy and unevenly distributed (Figure 83.3).
 - Limitations of thoracic radiography include a time lag between the onset and clearance of pulmonary edema in comparison to clinical signs and the presence of pre-existing lung pathology obscuring identification of pulmonary edema.
- Electrocardiography
 - Although electrocardiography is not able to diagnose pulmonary edema it can identify arrhythmias that may warrant institution of antiarrhythmic therapy.



■ **Figure 83.1** Left atrial enlargement and perihilar interstitial to alveolar pulmonary infiltrates in a poodle with congestive heart failure secondary to mitral valve disease.



■ **Figure 83.2** Generalized alveolar pulmonary pattern in a dog with dilative cardiomyopathy.



■ **Figure 83.3** Cardiomegaly and pulmonary edema in a cat with hypertrophic cardiomyopathy.

- **Echocardiography**
 - Although echocardiography is not able to diagnose pulmonary edema, it is very useful for detecting the presence and severity of underlying cardiac disease and guiding therapy tailored for that disease.
- **Cardiac catheterization**
 - Placement of a Swan-Ganz catheter to measure pulmonary arterial pressures and estimate left atrial pressure is rarely performed but may be useful for guiding therapy in animals with severe, life-threatening pulmonary edema or those with refractory congestive heart failure.
- **Biochemical profile**
 - Severe cardiac compromise may reduce the glomerular filtration rate and make it more difficult to manage animals that require aggressive preload or afterload reduction.
 - Electrolyte imbalances may exacerbate arrhythmias, reduce the effectiveness of some therapeutics, or increase the likelihood of developing drug toxicities.
- **Measurement of natriuretic peptides**
 - Recent studies suggest measurement of natriuretic peptides, including atrial natriuretic peptide or B-type natriuretic peptide, may help identify animals with severe cardiac compromise and may be useful at distinguishing animals with respiratory distress of cardiac origin and noncardiac origin.



THERAPEUTICS

- The therapeutic objectives for the management of cardiogenic pulmonary edema include resolution of the pulmonary edema, maintenance of adequate tissue perfusion pressure, and adequate delivery of blood flow to vital tissues. To achieve these goals it is important to use drugs with proven hemodynamic benefits and a rapid onset of action.

Drug(s) of Choice

- **Oxygen**
 - Supplemental oxygen is readily administered to compromised animals by providing an oxygen-enriched environment (i.e., oxygen cage) or via nasal insufflation.
- **Furosemide**
 - 2 to 4 mg/kg IV (dogs) and 1 to 2 mg/kg IV (cats)
 - These large doses may need to be repeated (initially every 1 to 2 hours) until the respiratory rate and dyspnea start to decline.
 - Once stable the dose should be reduced to 0.5 to 2 mg/kg every 8 to 12 hours, as dictated by clinical status.
 - Some animals will require more aggressive diuresis but care should be exercised because excessive administration may lead to profound dehydration, electrolyte depletion, renal failure, low cardiac output, and circulatory collapse.

- In dogs with severe mitral valve insufficiency (often those complicated with ruptured chordae tendineae) or severe dilated cardiomyopathy additional therapies that may be required include:
 - Nitroprusside: a potent balanced vasodilator.
 - Constant rate infusion typically administered at 2 to 5 $\mu\text{g/kg}$ per minute, diluted in 5% dextrose.
 - It is light sensitive and should not be infused with other agents so a second intravenous catheter should be placed for administration of additional intravenous drugs.
 - It promotes profound preload and afterload reduction so blood pressure should be continuously monitored.
 - Rapid administration rates may produce cyanide toxicity.
 - Discontinuation or a reduction in the infusion rate often promptly reverses side effects.
 - Dobutamine: a rapid acting positive inotropic agent.
 - Constant rate infusion typically administered at 5 to 15 $\mu\text{g/kg}$ per minute, diluted in 5% dextrose.
 - Although tachycardia/arrhythmias and vasodilation are uncommonly reported, ideally continuous ECG and blood pressure monitoring is performed.
 - Discontinuation or a reduction in the infusion rate often promptly reverses side effects.
 - Although not as potent as nitroprusside and dobutamine, in animals where it is impractical to administer these therapies attempts may be made to substitute either:
 - Pimobendan, 0.25 mg/kg PO twice a day
- or
- Hydralazine, 0.5 to 2.0 mg/kg PO twice a day
 - Sedative/tranquilizers: some animals with profound anxiety associated with their pulmonary edema may benefit from sedation.
 - Long-term management of animals with a history of cardiogenic pulmonary edema often includes diuretics, angiotensin-converting enzyme inhibitors, positive inotropes, β -blockers, calcium channel blockers, anti-arrhythmics, or other drug classes as dictated by the underlying disease.

Precautions/Interactions

- In animals with known cardiogenic pulmonary edema, intravenous fluids, other than those used to prepare a constant rate infusion, should be avoided.
- Potent afterload reducers should be used cautiously in cats with hypertrophic cardiomyopathy complicated by systolic anterior motion of the mitral valve.

Diet

- During the acute management of cardiogenic pulmonary edema food and water should be withheld.

- Once stabilized animals may have access to restricted water and food consumption.
- Low-sodium diets may be beneficial in the long-term management of animals with a previous history of cardiogenic pulmonary edema.

Activity

- During the acute management of cardiogenic pulmonary edema, strict rest should be implemented.
- After discharge, limited exercise can be resumed at the leisure of the animal but strenuous exercise should be avoided.



COMMENTS

Client Education

- Clients should be informed that in most instances the medications will need to be administered throughout the remainder of the animal's life.
- Clients should be educated about the importance of periodic rechecks and should be instructed to monitor for clinical signs that may signify recurrence of cardiogenic pulmonary edema.

Patient Monitoring

- Reductions in the respiratory rate and effort are the most reliable clinical signs that the cardiogenic pulmonary edema is resolving. These should be monitored and recorded at a minimum of hourly.
- Urine production should be monitored throughout hospitalization.
- A reduction in the body weight may suggest effective diuresis.
- Radiographic findings often lag behind clinical signs so treatment should be based on clinical status in addition to results of diagnostic tests.
- Mild, presumably prerenal azotemia and electrolyte imbalances are common in animals treated for congestive heart failure. Biochemical profiles should be performed at initial presentation and 5 to 7 days after institution of therapy/discharge from the hospital to monitor the renal status.
- Radiographs should be rechecked approximately 5 to 7 days after institution of therapy/discharge from the hospital to assess the efficacy of therapy.
- Additional follow up is dictated by the underlying cardiac disease, patient status and complicating factors.

Prevention/Avoidance

- Owners may not be able to specifically prevent the recurrence of pulmonary edema but they should make every effort to:
 - Closely monitor their animal's attitude, respiratory rate, appetite, and activity level daily.

- Develop a strict routine for administration and timing of cardiac medications.
- Follow up with instructions regarding periodic rechecks and diagnostic tests including radiographs, biochemical profiles, ECGs, and echocardiograms.

Possible Complications

- Complications, or side effects, of therapy are polyuria and polydipsia.
- Cardiogenic pulmonary edema often recurs as the cardiac disease progresses and clinical signs return or animals may die suddenly.

Expected Course and Prognosis

- Severe cardiogenic pulmonary edema is usually fatal if not treated rapidly and effectively.
- With appropriate treatment and monitoring, the short-term prognosis for animals with cardiogenic pulmonary edema, assuming they respond appropriately to therapy and complicating factors (e.g., severe cardiac arrhythmias, ruptured chordae tendinae, systemic thromboembolization) are absent, is fair.
- Animals with concurrent severe renal insufficiency or acute renal failure have a poor short-term prognosis.
- Most animals with heart disease that is severe enough to produce pulmonary edema have a guarded long-term prognosis and many ultimately succumb to their heart disease. The overall median survival time is dependent on the particular disease, the presence of complicating factors, and the individual response to therapy.

Synonyms

- Left-sided congestive heart failure

Abbreviations

- ECG: electrocardiogram
- IV: intravenously
- PDA: patent ductus arteriosus
- PO: by mouth

Suggested Reading

- Bulmer, BJ, and Sisson, DD. Therapy of heart failure. In: Ettinger, SJ, Feldman, ECG, eds. *Textbook of Veterinary Internal Medicine*, 6th ed., pp. 951–953. St. Louis: Elsevier, 2005.
- Fine, DM, Declue, AE, and Reinero, CR. Evaluation of circulating amino terminal-pro-B-type natriuretic peptide concentration in dogs with respiratory distress attributable to congestive heart failure or primary pulmonary disease. *J Am Vet Med Assoc* 2008;232:1674–1679.
- Prosek, R, Sisson, DD, Oyama, MA, and Solter, PF. Distinguishing cardiac and noncardiac dyspnea in 48 dogs using plasma atrial natriuretic factor, B-type natriuretic factor, endothelin, and cardiac troponin-I. *J Vet Intern Med* 2007;21:238–242.

Ware, WA, and Bonagura, JD. Pulmonary edema. In: Fox, PF, Sisson, DD, and Moise, NS, eds. *Textbook of Canine and Feline Cardiology, Principles and Clinical Practice*, 2nd ed., pp. 251–264. Philadelphia: W.B. Saunders, 1999.

Author: Barrett J. Bulmer

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Patti S. Snyder

Pulmonary Hypertension (PHT)



DEFINITION/OVERVIEW

- PHT is present when the mean, sustained pulmonary arterial pressure is greater than 25 mmHg. MPAP is related to the PVR and PBF as evidenced in the equation:

$$\text{MPAP} = (\text{PVR} \times \text{PBF}) + \text{mean pulmonary capillary wedge pressure}$$

- Historically PHT was classified as either primary (idiopathic) or secondary. But following identification that some conditions within the category of secondary PHT resembled idiopathic disease pathologically and in their response to treatment, the World Health Organization introduced a new classification scheme devised on the basis of mechanisms. The groups, with examples of associated veterinary conditions, are as follows:
 - Group I: Pulmonary arterial hypertension
 - Idiopathic.
 - PHT associated with systemic to pulmonary shunts.
 - PHT associated with portal hypertension.
 - PHT associated with drugs/toxins.
 - Group II: Pulmonary venous hypertension
 - Mitral valve insufficiency/mitral stenosis.
 - Myocardial disease with elevated left ventricular diastolic pressure.
 - Group III: PHT associated with chronic respiratory disease/hypoxemia.
 - Chronic obstructive pulmonary disease.
 - Interstitial lung disease.
 - Chronic exposure to high altitude.
 - Group IV: PHT associated with chronic pulmonary thromboembolism
 - Group V: PHT due to miscellaneous disorders directly affecting the pulmonary vasculature
 - Heartworms (*Dirofilaria immitis*)
 - *Angiostrongylus vasorum*



ETIOLOGY/PATHOPHYSIOLOGY

- The principal vascular changes that produce PHT include vasoconstriction, smooth-muscle cell and endothelial cell proliferation, and thrombosis. These processes

reduce the cross-sectional area of the pulmonary arterial bed and the pulmonary compliance thereby increasing PVR.

- Pulmonary endothelial cell dysfunction or injury likely contribute to these homeostatic imbalances via alteration of the complex interactions between various vasodilators (e.g., prostacyclin, nitric oxide) and vasoconstrictors (e.g., thromboxane A₂, endothelin-1, serotonin), growth inhibitors and mitogenic factors, and antithrombotic and prothrombotic determinants.
- Pulmonary venous hypertension secondary to myocardial disease in cats and myocardial and valvular disease in dogs may contribute to increased pulmonary arterial pressures via retrograde transmission of left atrial pressure to the pulmonary vascular bed, hypoxia-induced vasoconstriction of the pulmonary arteries, endothelial dysfunction, and vascular remodeling.
- Animals with PHT secondary to chronic respiratory disease presumably develop elevated pulmonary arterial pressure as a result from direct damage from the primary disorder, hypoxia-induced vasoconstriction, and vascular remodeling.

Systems Affected

- Respiratory
 - Coughing, respiratory distress, and tachypnea may manifest as a result of any primary underlying pulmonary disease.
 - Vascular remodeling and hypoxemia of exertion associated with PHT may also independently reduce lung compliance and contribute to respiratory compromise.
- Cardiovascular
 - Increased pulmonary arterial pressure contributes to right ventricular concentric hypertrophy in an effort to normalize ventricular wall stress.
 - Depending on the speed with which it develops and its severity, PHT may ultimately increase right ventricular end-diastolic and right atrial pressures producing right-sided heart failure.
 - Exertional syncope may occur secondary to hypoxemia, exercise-induced vasodilation, and an inability to increase cardiac output/pulmonary blood flow; dysrhythmias or reflex-induced bradycardia and hypotension have also been hypothesized to contribute to syncope.
- Musculoskeletal
 - Hypoxemia
 - Ventilation/perfusion mismatch
 - Lactic acidosis
 - Fixed cardiac output contributes to exercise intolerance and possibly weakness.
- Nervous
 - Hypoxemia may contribute to depression and lethargy.
 - When combined with dysrhythmias or activity, PHT contributes to syncope.
- Hepatobiliary
 - Concurrent right-sided congestion may contribute to cholestasis.



SIGNALMENT/HISTORY

- The signalment varies greatly based on the etiology that produces the PHT. Population characteristics from two large retrospective studies identified an age range from 2 months to 17 years although the largest percentages of dogs in both studies were younger than 10 years of age. Similarly there is a wide weight distribution wherein dogs weighed between 2 and 67 kg. There is no apparent sex predilection and it is difficult to predict if there are breed predispositions, although:
 - Dogs predisposed to degenerative mitral valve disease will be at increased risk for developing pulmonary venous hypertension.
 - Geographic distribution and heartworm preventative status may increase the likelihood of PHT associated with heartworm disease.
 - West Highland white terriers with interstitial pulmonary fibrosis may also be at higher risk for development of PHT.
- Depending on the etiology, severity, and rate of onset of the PHT owners may report a slow, insidious onset of clinical signs or an acute, rapid onset of life-threatening respiratory compromise.

Risk Factors/Causes

- Conditions that contribute to hypercoagulable states (e.g., protein-losing nephropathy, hyperadrenocorticism, neoplasia, and immune-mediated hemolytic anemia) may increase the risk for pulmonary thromboembolism and acute development of pulmonary hypertension.
- Acute development of PHT secondary to embolization of *Dirofilaria immitis* may occur following adulticide therapy.
- Large left-to-right congenital cardiac shunts may contribute to increased PBF and vascular remodeling, both of which contribute to PHT.
- Although it is generally accepted that dogs have low pulmonary vascular reactivity, there is some risk of developing mild to moderate PHT resulting from chronic hypoxemia associated with living at high altitude.

Historical Findings

- Exercise intolerance
- Coughing, tachypnea, or respiratory distress
- Syncope
- Abdominal distension/right-sided heart failure



CLINICAL FEATURES

- Coughing, tachypnea, or respiratory difficulty/orthopnea
- Crackles and wheezes during pulmonary auscultation

- Murmurs of tricuspid or pulmonic insufficiency
- A split S2 associated with delayed pulmonary valve closure
- Dysrhythmias
- Evidence of right-sided heart failure: jugular venous distension, positive hepatjugular reflux, hepatomegaly, and/or ascites
- Cyanosis
- Audible murmur or gallop correlating with the underlying etiology (e.g., left apical systolic murmur associated with mitral valve insufficiency or a left basilar continuous murmur associated with a left-to-right shunting PDA)



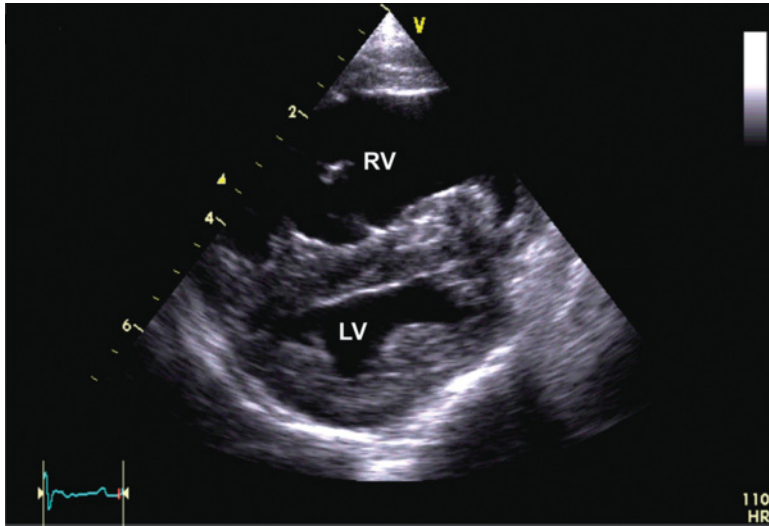
DIFFERENTIAL DIAGNOSIS

- Pneumonia
- Left-sided heart failure
- Heartworm disease
- Tracheal collapse
- Feline asthma (bronchitis)
- Obstructive lung disease
- Bronchitis
- Pulmonary fibrosis
- Neoplasia
- Noncardiogenic pulmonary edema
- Pulmonary contusions
- Inflammatory respiratory disease
- Many of these disorders may produce varying degrees of PHT; therefore, they are not mutually exclusive.



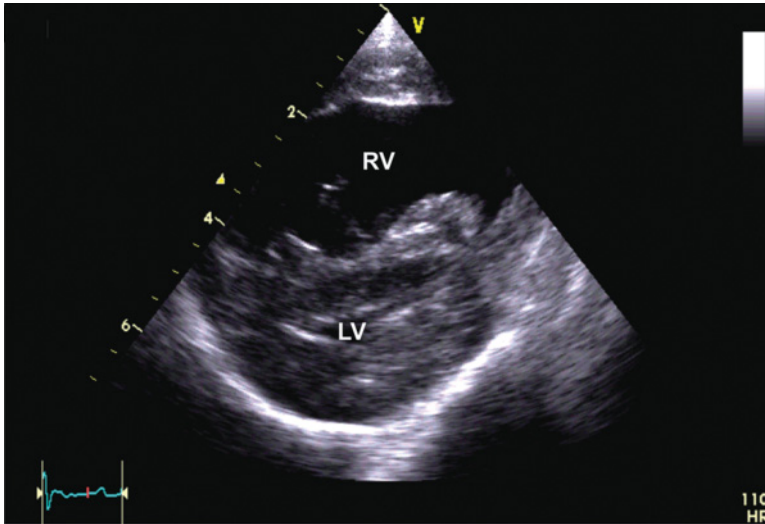
DIAGNOSTICS

- Animals with severe PHT may be in extremely critical condition and the diagnostic tests performed must be dictated by the clinical situation.
- Thoracic radiographs
 - Although thoracic radiographs are insensitive for identification of PHT they are useful for evaluation of underlying pulmonary disease.
 - In severe cases of PHT dilation of the main pulmonary artery and right-sided heart enlargement may be identified.
 - An enlarged caudal vena cava, ascites, hepatomegaly, and in some cases pleural effusion may accompany right-sided heart failure.
 - Left atrial and left ventricular enlargement with pulmonary venous congestion may accompany left-sided heart disease that produces pulmonary hypertension.
 - Dilated, tortuous, and truncated pulmonary arteries may be seen with heartworm disease.

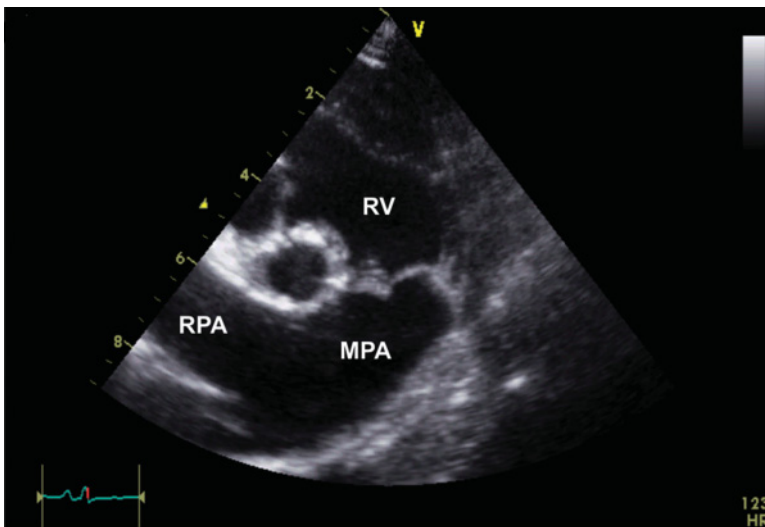


■ **Figure 84.1** A diastolic frame from a dog with severe pulmonary hypertension identified right ventricular (RV) dilation and thickening with interventricular septal flattening and reduced left ventricular (LV) diameters.

- Peripheral pulmonary arterial markings may abruptly stop with pulmonary thromboembolism.
- **Electrocardiography**
 - Although electrocardiography is not able to diagnose PHT, it may identify patterns of right ventricular enlargement, ST segment depression, or dysrhythmias that warrant institution of anti-arrhythmic drugs.
- **Echocardiography**
 - Two-dimensional, spectral, and color-flow Doppler echocardiography often allows for the noninvasive assessment of PHT.
 - Right ventricular concentric and eccentric hypertrophy may be identified in cases of moderate to severe PHT in response to increased afterload, elevated end-diastolic pressures and valvular insufficiencies.
 - Diastolic (Figure 84.1) or systolic (Figure 84.2) interventricular septal flattening may be identified when right ventricular pressure exceeds left ventricular pressure.
 - Dilation of the pulmonary artery and main branches (Figure 84.3) may be present.
 - Small end-diastolic left ventricular diameters may be identified resulting from reduced left ventricular preload in cases of severe PHT. This may also contribute to systolic anterior motion of the mitral valve.
 - Pulmonic stenosis or other complex defects of the right ventricular outflow tract can be ruled out as etiologies for the right ventricular hypertrophy.
 - Pulmonary arterial velocity profiles can be evaluated to increase the suspicion of PHT in the absence of quantifiable valvular insufficiencies.



■ **Figure 84.2** A systolic frame from a dog with severe pulmonary hypertension identified marked septal flattening and end systolic cavity obliteration that may contribute to systolic anterior motion of the mitral valve. RV, right ventricle; LV, left ventricle.



■ **Figure 84.3** Echocardiography may reveal marked dilation of the main pulmonary artery (MPA) and right pulmonary artery (RPA) in comparison to the aorta. RV, right ventricle.

- The presence of tricuspid insufficiency or pulmonic insufficiency enables estimation of pulmonary arterial pressure via use of the modified Bernoulli equation wherein the calculated pressure gradient = $4 \times (\text{velocity in meters/sec})^2$.
- Echocardiography enables identification of concurrent mitral valve insufficiency, myocardial disease or congenital heart disease that may contribute to PHT.

- Nuclear imaging and computerized tomography may be useful for identification of large pulmonary thromboemboli.
- Cardiac catheterization
 - Although infrequently performed, placement of a Swan-Ganz catheter to measure pulmonary arterial pressures, estimate left atrial pressure, perform thermodilution measures of cardiac output and calculate PVR may be considered the gold standard for the diagnosis of PHT.
 - Direct pulmonary arterial measures are further used in humans to assess the acute vasoreactivity of the pulmonary arteries to short-acting vasodilators and enable identification of candidates for chronic oral vasodilator therapy.
 - Pulmonary angiography may help identify large pulmonary thromboemboli although life-threatening complications have been reported in humans with severe, acute PHT.
- A complete blood count, biochemical profile, urinalysis, and heartworm serology should be performed to assess for underlying disease conditions that may contribute to PHT or hypercoagulability. These diagnostics also allow for investigation of consequences that may be attributable to the reduced cardiac output that frequently accompanies acute, severe PHT.

Pathologic Findings

- Dogs with PHT have been reported to have the same constrictive and complex lesions as those identified in people including four main histologic subsets:
 - Isolated medial hypertrophy
 - Medial hypertrophy-intimal thickening without plexiform lesion
 - Variations of the plexiform lesion and medial hypertrophy-intimal thickening was the most common pattern in one study.
 - Isolated arteritis
- Pulmonary and cardiac lesions vary markedly in animals with primary lung or heart disease, pulmonary thromboembolism, and heartworm disease.



THERAPEUTICS

- The therapeutic objectives for the management of pulmonary hypertension would ideally include (1) resolution of any underlying pulmonary disease or complicating factor contributing to the elevated pulmonary arterial pressure and (2) therapeutics aimed at reducing the pulmonary arterial pressure.
- Unfortunately many of the primary pulmonary diseases are severe and irreversible by the time PHT is diagnosed.
- Similarly although vasodilatory agents would seem beneficial they may actually be contraindicated in the face of PHT related to pulmonary disease as they could exacerbate ventilation/perfusion mismatch by dilating areas that are not ventilated.
- Further complicating the use of vasodilatory agents (e.g., amlodipine) is the fact that most traditional arterial vasodilators more effectively reduce systemic arterial

pressures and may produce symptomatic hypotension in the face of fixed right ventricular output.

- Many of the new and potentially promising vasodilatory agents used in humans, including endothelin receptor antagonists, constant rate infusion, and subcutaneous and oral synthetic prostacyclin analogs, are often cost prohibitive or difficult to administer in veterinary species.

Drug(s) of Choice

- Oxygen
 - Although dogs are generally accepted to have low pulmonary vascular reactivity, oxygen supplementation may be useful at reducing hypoxic induced arterial vasoconstriction.
- Sildenafil
 - A phosphodiesterase V inhibitor has been evaluated in a small number of dogs retrospectively.
 - There are varying reports regarding its ability to reduce echocardiographically determined pulmonary arterial pressure.
 - The retrospective studies suggest it may improve owner perceived clinical signs and quality of life.
 - Whether the same results hold true in a prospective, large-scale, blinded study is uncertain.
 - There are no studies that clearly define the appropriate dose of sildenafil for the management of PHT in dogs but anecdotally the author has started with 1 to 2 mg/kg PO every 12 hours safely.
- Diuretics, ACE inhibitors and positive inotropes are used as indicated to treat valvular disease or myocardial disease that is contributing to PHT.
- Abdominocentesis or thoracocentesis may need to be performed in animals compromised by ascites and pleural effusion, respectively.
- Atrial septostomy has been reported to improve hemodynamics and clinical signs in some humans with pulmonary arterial hypertension.
- Therapy in humans is usually palliative in an effort to prolong survival until a heart-lung transplantation can be performed.

Precautions/Interactions

- Excessive preload reduction may further limit cardiac output in animals with severe PHT producing weakness, lethargy, syncope, or sudden death.

Activity

- Many animals with moderate to severe PHT display exercise intolerance and should have restricted activity.
- Moderate to severe PHT may produce exertional syncope and increased myocardial oxygen demands may precipitate dysrhythmias.



COMMENTS

Client Education

- Clients should be informed that in most instances the medications will need to be administered throughout the remainder of the animal's life.
- Clients should be educated about the importance of periodic rechecks and should be instructed to monitor for clinical signs that may signify recurrence or progression of PHT.

Patient Monitoring

- Owners should be instructed to closely monitor general attitude, activity and exercise tolerance, respiration, and presence of right-sided heart failure.
- Follow up diagnostic tests should be dictated by the underlying disease process that is producing the PHT.
- Echocardiographic monitoring of pulmonary arterial pressure can be performed after institution of sildenafil. Up-titration may be attempted based on clinical status, echocardiographic findings and patient tolerance.

Prevention/Avoidance

- Owners should be cautioned about taking animals with moderate to severe PHT to excessive elevations.

Possible Complications

- Reported complications that may be attributed to sildenafil therapy include lethargy, somnolence, clear nasal discharge, erect ears, and cutaneous flushing.
- One report suggests severe hypotension and death may develop if sildenafil is combined with organic nitrates (i.e., nitroglycerin paste).

Expected Course and Prognosis

- The expected course and prognosis for animals with PHT are difficult to define because there are many etiologies that contribute to the disease.
- Overall, with the exception of heartworm disease with resolution or reduction of PHT following adulticide therapy, the prognosis for animals with moderate to severe pulmonary hypertension is guarded to grave.
- In most cases wherein PHT is secondary to chronic respiratory disease the underlying pulmonary pathology is severe and irreversible by the time PHT is diagnosed.
- Animals with mild to moderate PHT secondary to valvular disease or myocardial disease have a fair short-term prognosis and guarded long-term prognosis assuming the disease is progressive.

Abbreviations

- ACE: angiotensin-converting enzyme
- MPAP: mean pulmonary arterial pressure
- PBF: pulmonary blood flow
- PDA: patent ductus arteriosus
- PHT: pulmonary hypertension
- PO: by mouth
- PVR: pulmonary vascular resistance

Suggested Reading

- Bach, JF, Rozanski, EA, MacGregor, J, Betkowski, JM, and Rush, JE. Retrospective evaluation of sildenafil citrate as a therapy for pulmonary hypertension in dogs. *J Vet Int Med* 2006;20:1132–1135.
- Campbell, FE. Cardiac effects of pulmonary disease. *Vet Clin Small Anim* 2007;37:949–962.
- Johnson, L, Boon, J, and Orton, EC. Clinical characteristics of 53 dogs with Doppler-derived evidence of pulmonary hypertension: 1992–96. *J Vet Int Med* 1999;13:440–447.
- Kellum, HB, and Stepien, RL. Sildenafil citrate therapy in 22 dogs with pulmonary hypertension. *J Vet Int Med* 2007;21:1258–1264.
- Pyle, RL, Abbott, J, and MacLean, H. Pulmonary hypertension and cardiovascular sequelae in 54 dogs. *Intern J Appl Res Vet Med* 2004;2:99–109.
- Zabka, TS, Campbell, FE, and Wilson, DW. Pulmonary arteriopathy and idiopathic pulmonary arterial hypertension in six dogs. *Vet Pathol* 2006;43:510–522.

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Pyometra



DEFINITION/OVERVIEW

- Cystic endometrial hyperplasia—hormonally mediated, progressive pathologic change in the uterine lining
- Pyometra—secondary to cystic endometrial hyperplasia; develops when bacterial invasion of the abnormal endometrium leads to intraluminal accumulation of purulent exudate



ETIOLOGY/PATHOPHYSIOLOGY

- Normal cycling bitches—2-month diestrus, with ovarian secretion of progesterone after every estrus
- Repeated exposure of the endometrium to high concentrations of estrogen followed by high concentrations of progesterone without pregnancy; leads to cystic endometrial hyperplasia
- Bacteria—uterine secretions provide excellent media for growth; ascend from the vagina through the partially open cervix during proestrus and estrus; normal vaginal flora; *Escherichia coli* most common isolate
- Cats—may be the result of estrogen at estrus followed by a progestational phase, caused by induction of ovulation by coitus, spontaneous ovulation, or other (as yet undefined) stimuli
- Recent studies suggest that subclinical bacterial infections or foreign bodies may trigger pyometra in the absence of classical CEH.

Systems Affected

- Reproductive—accumulation of purulent material in uterine horns
- Renal/urologic—bacterial toxins may impair renal function due to impaired ADH activity and lead to isosthenuric or hyposthenuric urine.
- Hemic/lymphatic/immune—leukocytosis or leukopenia may be present
- Hepatobiliary—extrahepatic cholestasis with severe sepsis



SIGNALMENT/HISTORY

- Older bitches and queens (younger than 6 years of age) are at greater risk.

- Bitches with short interestrus intervals are at greater risk.
- Young animals—if treated with exogenous estrogen or progestagen
- Pyometra may be more prevalent, or prevalent at younger ages, in some family lines.

Risk Factors/Causes

- Administration of estrogenic or progestagenic medications to intact females
- Dogs—usually diagnosed 1 to 12 weeks after estrus
- Cats—onset relative to estrus more variable
- Pyometra of the uterine stump (stump pyometra) in spayed animals may develop any time after ovariectomy if exposed to estrogen from ovarian remnant or exogenous source.

Historical Findings

- Open cervix: purulent or bloody vulvar discharge
- Closed cervix: no vulvar discharge
- Increased drinking and urinating
- Depression, lethargy, and anorexia
- Vomiting and diarrhea in some cases



CLINICAL FEATURES

- Uterus—palpably large; careful palpation may allow determination of size; overly aggressive palpation may induce rupture; with open cervix may not be palpably large



■ **Figure 85.1** Purulent vaginal discharge in a dog with an open pyometra.

- Vulvar discharge—depends on cervical patency; sanguineous to mucopurulent (Figure 85.1)
- Depression and lethargy
- Anorexia
- Polyuria and polydipsia
- Vomiting
- Abdominal distension
- Fever or hypothermia



DIFFERENTIAL DIAGNOSIS

- Pregnancy
- Other causes of polyuria and polydipsia—diabetes mellitus; hyperadrenocorticism; primary renal disease
- Severe vaginal disease—vaginitis, foreign body, bleeding mass
- Hydrometra (serous intrauterine discharge); mucometra (mucoid intrauterine discharge); and hematometra (hemorrhagic intrauterine discharge)



DIAGNOSTICS

- CBC: Immature neutrophilia seen in 74 percent of cases; leukopenia can occur with sepsis; normal CBC also can occur
- Mild, normocytic, normochromic anemia
- Chemistry panel: Hyperglobulinemia and hyperproteinemia, azotemia with renal impairment
- ALT and ALP both high with septicemia or severe dehydration
- Electrolyte disturbances depend on clinical course.
- Urinalysis: Sample collected by catheterization of the urinary bladder (least traumatic and most diagnostically accurate): evaluate for secondary UTI, impairment of renal function; cystocentesis is contraindicated if pyometra is suspected, due to risk of puncturing enlarged uterus and wicking bacteria into abdominal cavity.
- Cytologic examination of vulvar discharge: Degenerative polymorphonuclear cells and bacteria; may be normal with closed cervix.
- Bacterial culture and sensitivity test of anterior vaginal sample, useful in determining appropriate antibiotic use
- Radiography detects a large uterus (cannot differentiate from pregnancy prior to 45 days of gestation).
- Ultrasonography best diagnostic tool for diagnosis of pyometra and selection of candidates for medical therapy
 - Assess size of uterus and extent of cystic endometrial hyperplasia; nature of uterine contents

- Rule out pregnancy 20 to 24 days after ovulation.
- Normal uterine wall: not visible as a distinct entity
- Pyometra or cystic endometrial hyperplasia associated with a thickened uterine wall (with or without hypoechoic cystic areas) and intraluminal fluid
- Pyometra may occur with pregnancy in dogs (rare).
- Vaginoscopy indicated only in dogs with purulent vulvar discharge and no apparent uterine enlargement; allows determination of site of origin of the vulvar discharge; not possible in cats

Pathological Findings

- Endometrium (dogs and cats)—described as cobblestone (either condition)
- Cystic endometrial surface—covered by malodorous, mucopurulent exudate; thickened because of increased endometrial gland size and cystic gland distension



THERAPEUTICS

- Determine if patient is desired for future breeding by owner and, if so, if she is a candidate for medical therapy (not septic or systemically affected, no free fluid in abdomen, uterine wall not thin, patient under the age of 6 years, owner willing to breed on next cycle).
- If patient is not planned for future breeding, correct dehydration, support renal function, start antibiotic therapy, and perform ovariohysterectomy.
- If patient is to be treated medically, start antibiotics pending culture results, and begin therapy with prostaglandin $F_{2\alpha}$ to lyse corpora lutea and cause myometrial contraction.

Drug(s) of Choice

Antibiotics

- Empirical, pending results of bacterial culture and sensitivity test
- Use in all patients with pyometra
 - Common choice is enrofloxacin (5–10 mg/kg PO every 24 hours)
 - Administration continued for 3 to 4 weeks

Prostaglandins $PGF_{2\alpha}$

- Doses listed below for native compound only; analogues not recommended
- Cats: 0.1 to 0.5 mg/kg SQ every 8 to 12 hours for 2 to 5 days until the size of the uterus nears normal
- Dogs: 0.05 to 0.25 mg/kg SQ every 8 to 12 hours for 3 to 7 days until no intrauterine fluid visible by ultrasound
- Less conventional protocols also exist for lower doses given five times daily (10 μ g/kg five times a day for 1 day, then 20 μ g/kg five times daily for 1 day and then 50 μ g/kg five times daily).

Cloprostenol

- Dogs: 1 µg/kg SQ daily for 7 to 14 days

Miscellaneous

- Aglepristone (10 mg/kg SQ days 1, 2, and 8) efficacy enhanced with concurrent treatment with prostaglandin; not available in United States
- Cabergoline (5 µg/kg PO daily for 7 to 14 days) used currently with prostaglandin to increase speed of luteolysis and cervical opening
- Misoprostol 1 to 3 µg/kg given intravaginally concurrently with prostaglandin $F_{2\alpha}$ to assist in opening cervix if needed

Precautions/Interactions

- $PGF_{2\alpha}$ and cloprostenol with closed-cervix pyometra cause strong myometrial contractions.
- May cause uterine rupture or force purulent exudate through the oviducts, causing secondary peritonitis
- $PGF_{2\alpha}$ and cloprostenol in a valuable breeding animal; always rule out pregnancy before administration.
- $PGF_{2\alpha}$ and cloprostenol not approved for use in dogs and cats
- Adverse effects of prostaglandins—referable to contraction of smooth muscle; include hypersalivation; emesis; defecation; intense grooming of the flanks and vulva (cats); appear within minutes of injection; subside within 30 to 60 minutes; severity diminishes throughout the treatment regimen; may be diminished by diluting the drug with an equal volume of sterile saline before subcutaneous injection and by walking dogs for 20 to 30 minutes after injection, antiemetics can also be utilized

Diet

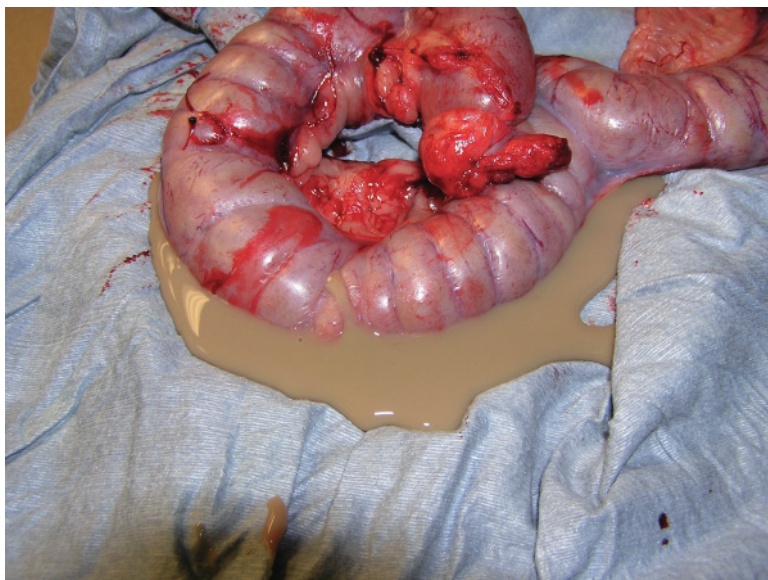
- Timing of feeding should avoid the hour before and the hour after $PGF_{2\alpha}$ administration to prevent vomiting of meal.

Activity

- Patients with pyometra typically are not interested in exercise and should be allowed to rest, apart from the walking post $PGF_{2\alpha}$ administration.

Surgical Considerations

- Pyometra (open and closed cervix)—ovariohysterectomy preferred treatment; chronic progressive disease (Figure 85.2)
- Closed-cervix pyometra—use caution during ovariohysterectomy; enlarged uterus may be friable and prone to rupture.
- Uterine rupture or leakage of purulent material from the uterine stump—repeated lavage of the peritoneal cavity with sterile saline



■ **Figure 85.2** Removal of pus-filled uterus at the time of ovariohysterectomy.

- Adequate fluid to maintain blood pressure and support renal function is necessary.
- Patients may have dramatic temperature drop after removal of progesterone source; exogenous heat support and monitoring of body temperature are important.



COMMENT

Client Education

- Inform client that ovariohysterectomy is the preferred treatment.
- Recommend medical treatment only for valuable breeding animals that are not azotemic and have an open cervix; warn client that except when breeding is planned, non-progestational, estrus-suppressing drugs (mibolerone) should be given for life.
- Warn client that medical treatment of closed-cervix pyometra can be associated with uterine rupture and peritonitis.
- Inform client that medical treatment does not cure underlying cystic endometrial hyperplasia in patients with either open- or closed-cervix pyometra but may enable some affected bitches and queens to reproduce.
- Patients treated medically can cycle sooner than expected due to shortening of the luteal phase of the cycle.

Patient Monitoring

- Medically treated patients should be monitored with ultrasound to gauge their progress, initially after 3 to 5 days of treatment, then every 2 days until resolution.

- After discharge, patients should be rechecked in 2 weeks for any vaginal discharge and overall health; ultrasound can be rechecked at this time.

Prevention/Avoidance

- Patient should be bred on next cycle and spayed after desired litter(s).
- If breeding is not planned, cycle should be suppressed in the bitch (no safe alternatives for this in the queen).

Possible Complications

- Infertility
- Uterine rupture
 - Bitch may enter estrus sooner after treatment than anticipated if medical treatment induced premature luteolysis.

Expected Course and Prognosis

- Dogs, medical treatment—underlying cystic endometrial hyperplasia still exists; predisposed to recurrence; breed patient to desired stud dogs in a timely manner; recommend ovariectomy as soon as breeding life is over; use of subfertile stud dogs not recommended, overall success in future reproduction 50 to 75 percent
- Cats, medical treatment, good success
- Surgical treatment, dogs and cats, if not septic and stable, good success; patients who are septic and critically ill, with significant renal impairment, prognosis is fair to guarded



COMMENTS

- Typically patients treated medically for pyometra still have underlying changes in the endometrium and should have estrus suppressed with anabolic steroid (mibolerone, from compounding pharmacy) until breeding is desired.
- Cycling will resume days to months after cessation of mibolerone (average 70 days).
- No safe estrus suppression drug is available for queens.

Abbreviations

- ADH: antidiuretic hormone
- ALT: alanine transaminase
- ALP: alkaline phosphatase
- CBC: complete blood count
- CEH: cystic endometrial hyperplasia
- PGF_{2α}: prostaglandin F_{2α}
- PO: by mouth
- SQ: subcutaneously
- UTI: urinary tract infection

Suggested Reading

- Feldman, EC, and Nelson, RW. Feline reproduction. In: Feldman, EC, Nelson, RW, eds. *Canine and Feline Endocrinology and Reproduction*, pp. 1035–1038. Philadelphia: Saunders, 2004.
- Johnston, SD, Root Kustritz, MV, and Olson, PN. Disorders of the canine uterus and uterine tubes (oviducts). In: *Canine and Feline Theriogenology*, pp. 206–224. Philadelphia: Saunders, 2001.
- Little, S. *Feline Reproduction: A Manual for Breeders and Veterinarians*. Manasquan, NJ: The Winn Feline Foundation, 2003.
- Pretzer, SD. Clinical presentation of canine pyometra and mucometra: A review. *Therio* 2008;70: 359–363.
- Verstegen, J, Dhaliwal, K, and Verstegen-Onclin, K. Mucometra, cystic endometrial hyperplasia, and pyometra in the bitch: Advances in treatment and assessment of future reproductive success. *Therio* 2008;70:364–374.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Margaret V. Root Kustritz

Pyothorax



DEFINITION/OVERVIEW

- Pyothorax is characterized by the accumulation of a septic purulent fluid within the pleural space.
- Pyothorax occurs in both dogs and cats, but occurs more commonly in cats.



ETIOLOGY/PATHOPHYSIOLOGY

- The most common cause of pyothorax in cats is bite wounds to the chest from other cats, but environmental contamination from penetrating thoracic injuries can also occur. Additional causes include rupture or perforation of the esophagus, trachea, or bronchi, migrating foreign bodies (grass awns) or lung parasites, bacterial pneumonia leading to lung abscesses and rupture, or iatrogenic contamination from thoracocentesis or thoracotomy.
- In dogs, pyothorax may result from penetrating wounds to the chest, neck, or mediastinum, esophageal perforations, lung parasites, bacterial pneumonia with abscessation and rupture, hematogenous or lymphatic spread from other septic foci, spread from cervical, lumbar, or sternal diskospondylitis, neoplasia with secondary abscessation, iatrogenic contamination from thoracocentesis or thoracotomy, and migrating foreign bodies such as grass awns.
- The most common bacterial isolates from cats with pyothorax are the anaerobes *Peptostreptococcus* spp, *Bacteroides* spp, *Fusobacterium* spp, *Prevotella* spp, and the aerobes *Pasteurella* spp and *Actinomyces* spp.
- The most common bacterial isolates from dogs are the anaerobes *Peptostreptococcus* spp, *Bacteroides* spp, *Fusobacterium* spp, and *Porphyromonas* spp, and the aerobes *Actinomyces* spp, *Pasteurella* spp, *Escherichia coli*, and *Streptococcus* spp. These bacterial isolates are similar to those identified from cats with the addition of the enteric, *E. coli*.
- Mixed populations of bacteria are often cultured from cats and dogs.
- Once bacterial infection enters the pleural cavity, the release of inflammatory mediators causes increased permeability of the endothelial lining of the pleural capillaries and impairment of lymphatic outflow. This results in accumulation of fluid, protein, and inflammatory cells in the pleural space. Increased protein concentration in the

pleural fluid causes an increased oncotic pressure, favoring additional fluid movement out of the capillaries and into the pleural space.

Systems Affected

- Respiratory
- Hemic/Lymphatic/Immune
- Cardiovascular
- Endocrine/Metabolic



SIGNALMENT/HISTORY

Risk Factors/Causes

- Cats from multicat households.
- The hunting and working breeds of dogs, possibly caused by aspiration of grass awns and subsequent migration.

Historical Findings

- Presentation is often delayed for weeks to months after inciting incident.
- Penetrating thoracic injuries are often healed by the time respiratory compromise develops, making diagnosis of the underlying cause difficult to impossible.
- Dogs—exercise intolerance, respiratory difficulty or distress, reluctance to lay down, anorexia, lethargy, and cough are common.
- Cats—respiratory difficulty or distress, depression, lethargy, pallor, anorexia, and pain.



CLINICAL FEATURES

- Clinical presentation can vary widely, from mild respiratory signs to collapse from severe septic shock.
- Findings usually include varying degrees of respiratory distress: increased respiratory effort, tachypnea, dull lung sounds ventrally, harsh sounds dorsally and orthopnea.
- Signs of septic shock, such as hyperthermia or hypothermia, tachycardia (or in cats, bradycardia), injected or pale mucous membranes, and bounding or weak pulses.
- Recent weight loss and a poor body condition may be noted.
- Additional findings may include depression and dehydration.



DIFFERENTIAL DIAGNOSIS

- Other causes of pleural effusion: chylothorax, heart failure, hemothorax, neoplasia, hypoproteinemia, or FIP (cats).

- Other pleural space disease: diaphragmatic hernia or neoplasia
- Pulmonary disease: pneumonia or pulmonary abscesses.



DIAGNOSTICS

Complete Blood Count/Biochemistry

- CBC—usually marked leukocytosis, with or without an increased number of band neutrophils and toxic change, but in severe cases, a leukopenia and degenerative left shift may be found. Anemia may be present if the pyothorax has been chronic.
- Biochemical results may be normal, or may show changes consistent with sepsis, including hypoalbuminemia, hypoglycemia and increased ALT and total bilirubin. Changes consistent with dehydration and hemoconcentration are seen in some patients.

Other Laboratory Tests

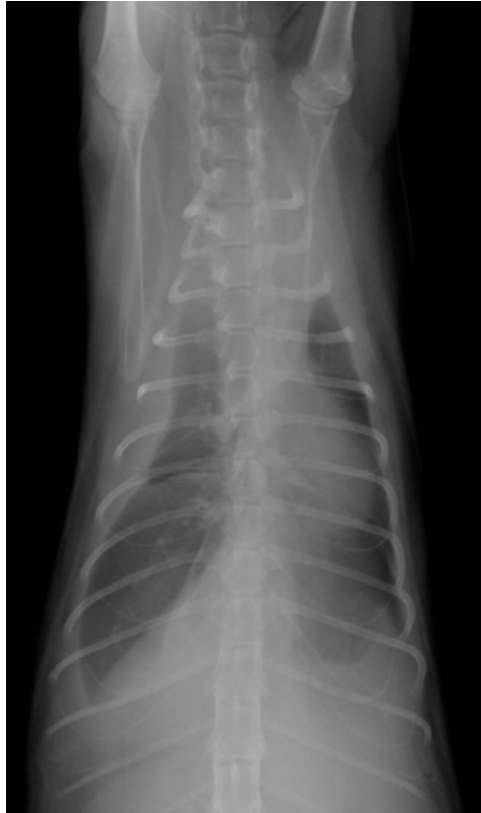
- Retrovirus testing (cats)—FeLV or FIV positive status may complicate treatment and increase risk of recurrence.

Imaging

- Thoracic radiography—useful in confirming the presence of pleural effusion, but patients in respiratory distress may not tolerate radiographs. More helpful in searching for underlying causes once pleural effusion has been removed. Useful to determine if disease is bilateral or unilateral (Figures 86.1 and 86.2).
- Thoracic ultrasonography—can identify abscesses or masses in pulmonary parenchyma or mediastinum.
- Thoracoscopy—can be used to explore thoracic cavity. May be helpful in some cases to flush thoracic cavity, determine cause, and remove affected lung lobes.

Diagnostic Procedures

- Thoracocentesis—indicated if there is a suspicion of pleural effusion. It is often a thick, opaque and foul-smelling fluid and may be flocculent. Samples should be evaluated through cytology, culture, and cell counts.
- Fluid analysis—exudate, protein > 3 g/dl, nucleated cell count $> 7 \times 10^9$ /l.
- Cytology—neutrophils, often degenerative with signs of toxicity and bacteria, both intracellular and extracellular. Absence of bacteria does not rule out pyothorax, especially if antibiotics have been administered. Sulfur granules may also be seen. If the pyothorax is chronic, there may be increasing numbers of macrophages and plasma cells.
- Aerobic and anaerobic culture and sensitivity testing.
- Fungal culture depending on geographic location.



■ **Figure 86.1** Radiograph of a cat with pyothorax showing bilateral pleural effusion. Due to the presence of the effusion, the pulmonary parenchyma cannot be well evaluated for the presence of lung abscesses, foreign bodies, masses, or other underlying pathology.



■ **Figure 86.2** Radiograph of a cat with pyothorax showing pleural effusion. Due to the presence of the effusion, the pulmonary parenchyma cannot be well evaluated for the presence of lung abscesses, foreign bodies, masses, or other underlying pathology.

Pathological Findings

- Pleuritis, pleuropneumonia, or pneumonia.
- Underlying etiology including lung lobe abscesses, puncture wounds into thoracic cavity, or foreign bodies may occasionally be seen.



THERAPEUTICS

- Initial stabilization—oxygen therapy, minimal handling and stress, thoracocentesis, intravenous catheter and intravenous fluids, including shock boluses if indicated.
- Thoracic drainage—mainstay of therapy. Can be accomplished by intermittent thoracocentesis or by placement of thoracostomy tubes, with intermittent aspiration or continuous drainage. Thoracostomy tubes are preferred because they allow for more complete drainage of the thoracic cavity. Bilateral thoracostomy tubes are preferred unless effusion is unilateral (Figure 86.3).
- Lavage of the thoracic cavity with warm physiological saline or other balanced electrolyte solutions at 20 ml/kg, instilled over 10 to 15 minutes, every 6 to 24 hours have been recommended. Not recommended unless effusion is too thick to aspirate through chest tube due to risk of nosocomial infection and potential inability to retrieve fluid.



■ **Figure 86.3** Cat with a chest tube in place to allow for frequent intermittent drainage of pleural effusion from a pyothorax.

Drug(s) of Choice

Antimicrobials

- Broad-spectrum antimicrobials—Gram-positive, Gram-negative, and anaerobic coverage until culture and sensitivity results are available. Broad-spectrum is essential due to frequency of infection with mixed bacterial population.
- Administer parenteral antibiotics while patient is critical and then switch to oral once stabilized.
- Adjust antibiotic therapy once culture and sensitivity results are available.
- Continue for several months following discharge from the hospital.
- Fluid therapy—maintenance rates or higher if pleural effusion is still being produced. Essential to keep patient hydrated so effusion can be aspirated via thoracostomy tubes or thoracocentesis.
- Clindamycin 11 mg/kg IV every 8 to 12 hours and enrofloxacin 10 to 15 mg/kg IV every 24 hours are excellent initial choices for dogs.
- Clindamycin 11 mg/kg IV every 8 to 12 hours and cefotaxime 15 mg/kg IV every 6 hours initially for cats.
- Long-term antibiotic therapy depends on culture and sensitivity testing but potentiated penicillins such as amoxicillin/clavulanic acid 22 mg/kg every 8 to 12 hours are often effective.

Analgesics

- Should be administered post-thoracostomy tube placement and while tubes are in place or post-thoracotomy.
- Intrapleural bupivacaine (1.5 mg/kg every 6–8 hours) via the thoracostomy tube may provide some analgesia, often not sufficient alone.
- Opiates such as hydromorphone 0.1 to 0.2 mg/kg IV or IM every 4 to 6 hours or fentanyl CRI 2 to 5 µg/kg per hour are often effective.

Precautions/Interactions

- Care with choice of antibiotics; aminoglycosides may cause acute renal failure, especially in patients that are not properly hydrated prior to initiating them. Potentiated sulfas may cause KCS, ITP, polyarthropathy, and other immune-mediated disease.

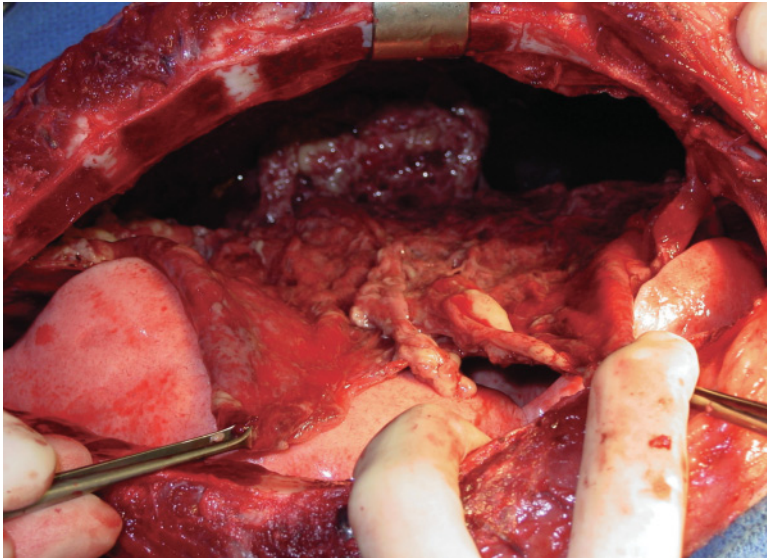
Activity

- Light activity (short walks) while hospitalized should be encouraged to prevent atelectasis.
- Restriction of activity to moderate level when discharged from hospital until resolution of radiographic signs.

Surgical Considerations

Cats

- Medical treatment is usually successful.



■ **Figure 86.4** Intraoperative picture of a 4-year-old intact male Weimaraner with pyothorax showing a very thickened, abnormal mediastinum, normal lung in the near field (*to the left of the forceps*), and very diseased lung in the far field (*just beneath the retractor*). A left pneumonectomy, partial excision and debridement of the mediastinum, and lavage of the thoracic cavity were performed. The underlying etiology of the pyothorax was not identified.

- Surgery is indicated if not responding to medical therapy after a week or so, or if surgical lesion (abscessed lung lobe or foreign body) is identified.

Dogs

- Have improved outcome with surgical intervention. Surgery should be considered without first trying medical treatment.

Surgical Treatment

- Requires a complete exploratory thoracotomy to identify and remove any necrotic tissue or foreign material, as well as complete lavage of the thoracic cavity (Figure 86.4).
- Samples for aerobic and anaerobic culture can be obtained at surgery.
- Options include median or sternotomy or lateral thoracotomy. Median sternotomy is preferred because it allows for full evaluation of the right and left hemithoraces.

Postoperative Care

- Patients require intensive care and monitoring, especially for the first 24 to 48 hours after surgery.
- Septic shock and SIRS may develop.

- Fluid therapy in the postoperative phase is very important and often consists of crystalloids, colloids, and blood products.
- Vasopressors may be needed to treat refractory hypotension once volume expansion has been accomplished.
- Respiratory, acid-base, and electrolyte abnormalities should be evaluated and treated, as needed.
- Patients are at risk for the development of DIC and need to have their coagulation parameters monitored closely.
- Daily evaluation of the CBC and cytology of the pleural effusion.



COMMENTS

Client Education

- Clients must be prepared for cost of treatment and long-term follow-up care.

Patient Monitoring

- In hospital—requires intensive care monitoring including respiratory rate/effort, heart rate, blood pressure, fluid ins/outs, temperature, oxygenation, pain management, nutrition monitoring, electrolyte, and acid-base balance.
- CBC and thoracic radiographs should be monitored every few days initially, then at increasing intervals.
- Once discharged, recheck examinations every few weeks for CBC and thoracic radiographs. Antibiotics should be continued until several weeks after resolution of radiographic changes.

Prevention/Avoidance

- Cats from single cat households have reduced risk.
- Dogs should avoid hunting if possible.

Possible Complications

- Sepsis, septic shock, SIRS, death
- Recurrence of pyothorax, especially in dogs treated medically
- Complications from thoracostomy tube including pneumothorax, hemothorax, or nosocomial infection
- Fibrosing pleuritis (uncommon)

Expected Course and Prognosis

- With appropriate therapy (antibiotics and medical or surgical management depending on species), prognosis is fair to good.
- Outpatient therapy with antibiotics and intermittent thoracocentesis has a poor prognosis.

- Recurrence rate is low for cats treated medically and for dogs treated surgically.
- Many patients may be euthanized due to owners' financial constraints.

Synonyms

- Empyema
- Purulent pleuritis

Abbreviations

- ALT: alanine transaminase
- CBC: complete blood count
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- FeLV: feline leukemia virus
- FIP: feline infectious peritonitis
- FIV: feline immunodeficiency virus
- IM: intramuscularly
- ITP: idiopathic thrombocytopenic purpura
- IV: intravenously
- KCS: keratoconjunctivitis sicca
- SIRS: systemic inflammatory response syndrome

Suggested Reading

- Rooney, MB, and Monnet, E. Medical and surgical treatment of pyothorax in dogs: 26 cases (1991–2001). *J Am Vet Med Assoc* 2002;221:86–92.
- Scott, JA, and Macintire, DK. Canine pyothorax: pleural anatomy and pathophysiology. *Comp Cont Ed Pract Vet* 2003;25:172–178.
- Scott, JA, and Macintire, DK. Canine pyothorax: clinical presentation, diagnosis, and treatment. *Comp Cont Ed Pract Vet* 2003;25:180–193.
- Waddell, LS, Brady, CA and Drobatz, KJ. Risk factors, prognostic indicators, and outcome of pyothorax in cats: 80 cases (1986–1999). *J Am Vet Med Assoc* 2002;21:819–824
- Walker, AL, Jang, SS, and Hirsch, DC. Bacteria associated with pyothorax of dogs and cats: 98 cases (1989–1998). *J Am Vet Med Assoc* 2000;216:359–364

Author: Lori. S. Waddell

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Mark Rishniw

Raisin and Grape Toxicity



DEFINITION/OVERVIEW

- Syndrome of vomiting, diarrhea, and ARF secondary to ingestion of raisins or grapes.



ETIOLOGY/PATHOPHYSIOLOGY

- Mechanism of ARF unknown
- Acute tubular necrosis, possibly secondary to ischemic insult to kidneys
- Degeneration of glomerular basement membrane
- Tubular obstruction with proteinaceous debris and renal casts
- Oliguric to anuric renal failure



■ **Figure 87.1** Induction of emesis in a dog that ingested chocolate-covered raisins.

Systems Affected

- GI: vomiting and diarrhea, often with visible remnants of raisins and/or grapes (Figure 87.1)
- Renal: ARF; isosthenuria to hyposthenuria, oliguria to anuria, azotemia, or uremia
- Metabolic: metabolic acidosis, hyper- or hypokalemia, hyperphosphatemia, or hypercalcemia
- Cardiovascular: atrial standstill possible with severe hyperkalemia



SIGNALMENT/HISTORY

- Primarily dogs, but anecdotally reported in cats

General Comments

- Vomiting and diarrhea within 24 hours of ingestion of raisins or grapes
- Lethargy
- Oliguria that can progress to anuria

Historical Findings

- Witnessed ingestion of raisins or grapes
- Findings of chewed boxes of raisins
- Visible grapes or raisins in vomitus or diarrhea
- Lethargy
- Inappetence
- Diarrhea
- Vomiting

Physical Examination

- Lethargy
- Dehydration
- Vomitus staining on muzzle
- Uremic ulceration in oral cavity
- Physical examination may be normal in early stages of ingestion.

Risk Factors/Causes

- Access to grapes or raisins
- Free roaming
- Pre-existing renal disease
- Pre-existing vomiting, diarrhea, dehydration, or hypotension
- Ingestion of even small quantities of raisins or grapes
- Toxic principle remains unknown.

- Ethylene glycol, herbicides, chlorinated hydrocarbon, carbamates, organophosphates, mycotoxins, and ochratoxin A all negative when tested



CLINICAL FEATURES

- Vomiting
- Diarrhea
- Lethargy
- Anorexia
- Abdominal pain
- Ataxia
- Weakness
- Decreased urination



DIFFERENTIAL DIAGNOSIS

- Leptospirosis
- Pyelonephritis
- Urethral or ureteral obstruction
- Toxins
 - Ethylene glycol
 - Cholecalciferol rodenticide
 - Melamine
 - Aminoglycoside antibiotics
 - NSAID
 - Easter lily
- GI Disease
 - GI obstruction
 - Hemorrhagic gastroenteritis
 - Dietary indiscretion
 - Pancreatitis
 - Viral or bacterial enteritis
- Hypoadrenocorticism
- Perform a thorough history and physical examination to determine risk and potential for exposure to grapes and/or raisins and to rule out other causes of acute renal failure



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis (Tables 87.1 and 87.2)

Other Tests

- Ethylene glycol negative
- Leptospirosis urine PCR and serum titers negative

TABLE 87.1 Biochemical or Complete Blood Count Abnormalities in Affected Patients

| Abnormality | Percentage of Affected Patients (%) |
|--|-------------------------------------|
| Azotemia (elevated blood urea nitrogen and creatinine) | 100 |
| Hypercalcemia | 63 |
| Hyperphosphatemia | 90 |
| Elevated Calcium × Phosphorus Product | 95 |
| Hyperkalemia | 45 |
| Hyponatremia | 33 |
| Hypochloremia | 33 |
| Elevated Anion Gap | 69 |
| Elevated Alkaline Phosphatase | 24 |
| Elevated Alanine Aminotransferase | 65 |
| Thrombocytopenia | 27 |
| Anemia | 41 |
| Elevated Lipase | 41 |

TABLE 87.2 Urinalysis Abnormalities and Percentage of Affected Patients

| Abnormality | Percentage of Affected Patients (%) |
|-----------------------|-------------------------------------|
| Isosthenuria | 41 |
| Hyposthenuria | 21 |
| Proteinuria | 56 |
| Glucosuria | 50 |
| Microscopic hematuria | 58 |
| White blood cells | 67 |
| Crystalluria | 33 |
| Cylindruria | 21 |

Imaging Modalities

- Radiographs
 - Microcardia and small caudal vena cava on thoracic radiographs
 - Possibly pulmonary edema as anuria progresses despite intravenous fluid therapy
- Ultrasound
 - Hyperechoic kidneys
 - Renomegaly
 - Perirenal fluid
 - Renal pelvis dilation
 - Hyperechoic mesentery near pancreas
 - Hypoechoic pancreas



THERAPEUTICS

- Induction of emesis within several hours of ingestion, followed by activated charcoal
 - 0.03 to 0.04 mg/kg IV apomorphine
- Intravenous crystalloid fluids
 - Calculate dehydration deficit, and replace over 24 hours.
 - Intravenous fluid diuresis (two to three times maintenance) shortly after ingestion
- Control nausea and vomiting.
- Maintain blood pressure and normotension.
- Stimulate urine output.
- Peritoneal or hemodialysis in anuric patients

Drug(s) of Choice

Diuretic

- Furosemide 2 to 4 mg/kg IV at 30-minute intervals, or 1 mg/kg per hour IV CRI
- Mannitol
 - 0.5 to 1 gram/kg IV slowly over 20 minutes
 - Use caution in overhydrated patients, or those with pulmonary edema, tubular obstruction, or known cardiac disease.

Calcium Channel Blockade

- Diltiazem
 - 0.3 to 0.5 mg/kg slow IV over 10 minutes, then 1 to 5 µg/kg per minute IV CRI
 - Use caution as hypotension could occur.
 - Can be used in conjunction with furosemide
 - Monitor body weight carefully, as diuresis can occur and lead to excessive fluid loss.

- Dopamine (2–5 mcg/kg per minute IV CRI)
- Fenoldopam (0.1–1 µg/kg per minute IV CRI)
- Phosphate binders

Anti-Emetics

- Dolasetron (0.6 mg/kg IV every 24 hours)
- Ondanzetron (1 mg/kg IV every 8 to 12 hours)
- Cerenia (1 mg/kg SQ, 2 mg/kg PO)
- Metoclopramide (1–2 mg/kg per day IV CRI)

H₂ Blockers

- Famotidine
 - 0.5 to 1 mg/kg IV every 12 hours
- Ranitidine
 - 0.2 to 2 mg/kg IV, PO every 8 to 12 hours
- Cimetidine
 - 5 mg/kg IV every 6 to 8 hours

Proton Pump Inhibitors

- Omeprazole
 - 0.5 to 1 mg/kg PO every 12 hours
- Pantoprazole
 - 1 mg/kg IV

Gastroprotectants

- Sucralfate (0.25–1 g PO twice a day)
 - Treat hyperkalemia
- Insulin and Dextrose
 - 0.25 to 0.5 units/kg IV regular insulin, followed by 1 g dextrose IV per unit of insulin administered, followed by 2.5% dextrose CRI
- Sodium bicarbonate
 - 0.25 to 1 mEq/kg IV
- Calcium chloride or calcium gluconate
 - 0.5 to 1 mL/kg of 10% solution IV over 10 to 20 minutes, monitor ECG continuously



COMMENTS

- Central venous pressure
- Urine output; ins and outs
- Blood pressure

- ECG
- Body weight
- Daily to twice daily evaluation of BUN, creatinine, hematocrit, Hct, platelet count, electrolytes, and glucose

Possible Complications

- Aspiration pneumonia secondary to vomiting
- Pulmonary edema
- Hypertension
- Multiple organ failure/MODS
- Cerebral edema
- DIC
- Seizures
- Coma
- Death

Histopathology

- Severe diffuse tubular degeneration
- Proteinaceous and cellular debris
- Mineralization of glomerular basement membrane
- Glomerular congestion

Expected Course and Prognosis

- Generally favorable if treatment is initiated immediately after witnessed ingestion
- Overall, 53 percent survival in affected cases
- Potential for long-term renal insufficiency
- Negative prognostic indicators include oliguria or anuria, weakness, elevated calcium x phosphorus product, metabolic acidosis

Abbreviations

- ARF: acute renal failure
- BUN: blood urea nitrogen
- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- GI: gastrointestinal
- Hct: hematocrit
- IV: intravenously
- MODS: multiple organ dysfunction syndrome
- NSAID: nonsteroidal anti-inflammatory drug
- PCR: polymerase chain reaction
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Eubig, PA, Brady, MS, Gwaltney-Brant, SM, et al. Acute renal failure in dogs after the ingestion of grapes or raisins: a retrospective evaluation of 43 dogs (1992–2002). *J Vet Int Med* 2005;19: 663–674.

Mazzaferro, EM, Eubig, PA, Hackett, TB, et al. Acute renal failure associated with raisin or grape ingestion in 4 dogs. *J Vet Emerg Crit Care* 2004;14(3):203–212.

Porterpan, B. Raisins and grapes: potentially lethal treats for dogs. *Vet Med* 2005;May:346–350.

Author: Elisa M. Mazzaferro

Retinal Detachment



DEFINITION/OVERVIEW

- Separation of the retina from the underlying choroid.
- Anatomically, the separation of the photoreceptor layer from the retinal pigment epithelial layer of the retina.

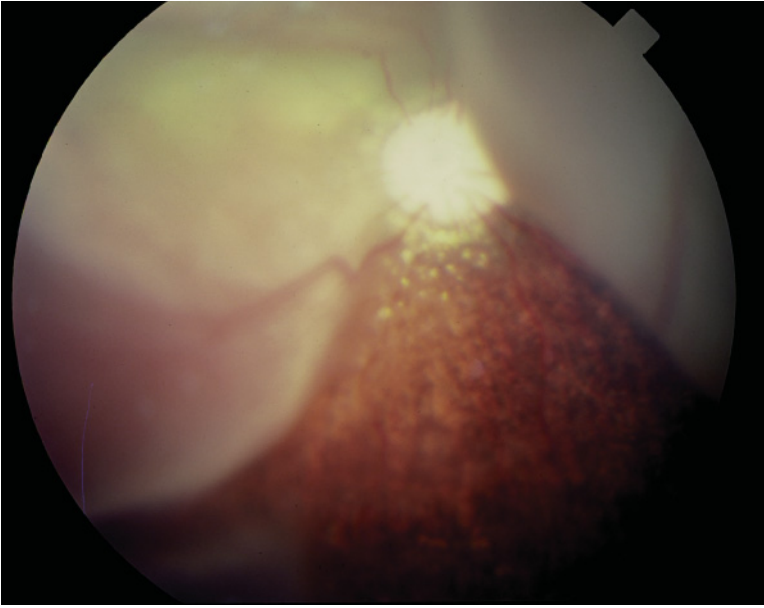


ETIOLOGY/PATHOPHYSIOLOGY

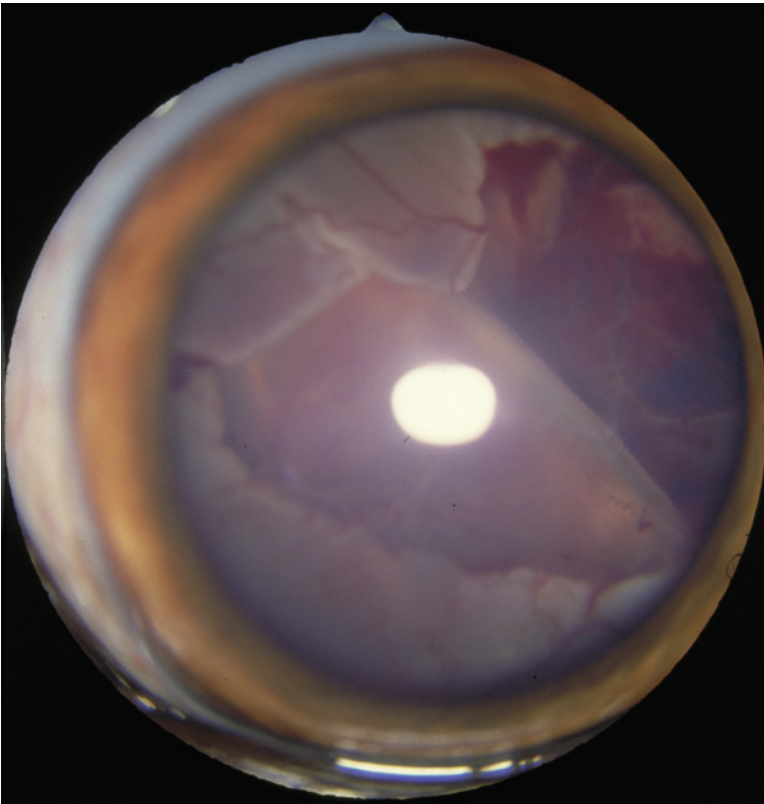
- There are five main types of retinal detachments:
 - Serous detachments (Figure 88.1)
 - Accumulation of exudates or blood under the retina (Figure 88.2)
 - Exudate is due to infectious causes (i.e., viral, fungal, or protozoal)
 - Hemorrhage is caused by systemic hypertension (a very common cause in cats), coagulopathies, trauma or idiopathic (steroid-responsive retinal detachment).
 - Traction band detachments
 - Fibrous bands attaching the vitreous to the retina contract and pull retina off; secondary to uveitis or trauma.
 - Vitreous degeneration
 - Liquifaction of the vitreous secondary to aging or chronic inflammation allows the vitreous to seep under the retina.
 - Congenital
 - Not a true detachment but failure of the embryologic layers to unite; seen in collie eye anomaly, retinal dysplasia (Figure 88.3)
 - Iatrogenic
 - After cataract surgery

Systems Affected

- Ophthalmic



■ **Figure 88.1** Fundic photograph of a dorsal, serous, retinal detachment. Note the veil-like structure covering the tapetum. This is the detached retina.



■ **Figure 88.2** Photograph of a detached retina taken through the pupil. Note the blood vessels in the retina and the hemorrhages.



■ **Figure 88.3** Fundic photograph of a circumscribed area of retinal detachment (*white arrow*) due to retinal dysplasia. The worm-like areas are dysplastic retina (*retinal folds*).



SIGNALMENT/HISTORY

- No breed or sex predilections

Risk Factors/Causes

- Dogs undergoing cataract surgery are at a higher risk and therefore those breeds predisposed to cataracts are at risk.

Historical Factors

- Vision loss—if unilateral may be difficult for owner to discern.
- Owner may notice cloudiness or redness of affected eye or the presence of a floating white tissue in pupil.



CLINICAL FEATURES

- Acute vision loss—if detachments are incomplete, visual field losses may be present and are very difficult to detect.
- A white sheet of tissue may be visible through the pupil, behind the lens sheet; it may contain blood vessels and possibly areas of hemorrhage.
- Pupil may be dilated and unresponsive if bilateral detachment
 - If unilateral, mild mydriasis in affected eye is present due to presence of consensual light response from other eye.
 - Direct pupillary light response in affected eye is absent.



DIFFERENTIAL DIAGNOSIS

- Any disease that causes acute blindness (e.g., SARD, acute hyphema or vitreal hemorrhage, diabetic cataracts).



DIAGNOSTICS

- Ophthalmoscopy—direct visualization of the detached retina
- Ocular ultrasound—if the posterior part of the eye cannot be seen due to cataracts or intraocular hemorrhage
- Complete blood count: To rule out infection or bleeding disorder; serum chemistry profile to assess renal function
- Systemic blood pressure measurement: To detect hypertension (especially important in cats)
- Cardiac evaluation for cardiomyopathy



THERAPEUTICS

- To optimize the environment for retinal reattachment; reattachment is not possible in congenital detachment.

Drug(s) of Choice

- Treat the primary cause—Hypertensive therapy (e.g., amlodipine in cats; 0.625 mg to 1.25 mg orally once to twice daily per cat).
- Appropriate systemic antimicrobials if infectious disease is suspected.
 - Systemic corticosteroids can be administered if steroid-responsive retinal detachment is suspected; contraindicated in infectious diseases.

Precautions/Interactions

- Systemic corticosteroids are contraindicated if infectious disease is suspected.
- Corticosteroids should not be given in conjunction with NSAIDs.

Diet

- No special diet is needed except if systemic hypertension is causative.

Surgical Considerations

- Retinal reattachment surgery, done by some veterinary ophthalmologists
- Partial detachments may be prevented from progressing by laser retinopexy around the edges of the detachment.



COMMENTS

Client Education

- The patient should be kept quiet with minimal activity or excitement.
- Because the animal usually goes blind he or she may become confused.
- Distribution of references to caring for blind dogs (see *Suggested Reading*).

Patient Monitoring

- Frequent rechecks are recommended early in the disease (e.g., weekly); in cases of hypertension, blood pressure should be checked and medications adjusted accordingly.

Prevention/Avoidance

- Early detection of hypertension (e.g., monitoring blood pressure in older cats) can prevent retinal detachment.
- Discourage breeding of dogs affected with CEA or retinal dysplasia to prevent genetic transmission.

Possible Complications

- Permanent blindness

Expected Course and Prognosis

- Guarded prognosis; reattached retinas can regenerate depending on cause and duration of detachment
- Better prognosis if detachment is due to serous subretinal exudate secondary to hypertension

Synonyms

- Retinal separation

Abbreviations

- CEA: collie eye anomaly
- NSAIDs: nonsteroidal anti-inflammatory drugs
- SARD: sudden acquired retinal degeneration

Suggested Reading

Levin, CD. *Living with Blind Dogs*. Oregon City, Oregon: Lantern Publications, 1998.

Martin, CL. Vitreous and ocular fundus. In: *Ophthalmic Disease in Veterinary Medicine*, pp. 401–470. London: Manson Publishing, 2005.

Narfstrom, K, and Petersen-Jones, S. Diseases of the canine ocular fundus. In: Gelatt, KN, ed. *Veterinary Ophthalmology*, 4th ed., pp. 944–1025. Ames, IA: Blackwell Publishing, 2007.

Ofri, R. Retina. In: Maggs, DJ, Miller, PE, and Ofri, R. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed., pp. 285–286. St. Louis: Saunders, Elsevier, 2008.

Vainisi, SJ, Wolfer, JC, and Smith, PJ. Surgery of the canine posterior segment. In: Gelatt, KN, ed. *Veterinary Ophthalmology*, 4th ed., pp. 1026–1058. Ames, IA: Blackwell Publishing, 2007.

Author: Juliet R. Gionfriddo

Schiff-Sherrington



DEFINITION/OVERVIEW

- Forelimb extensor hypertonia with hindlimb paralysis (Figure 89.1) caused by an acute complete thoracolumbar (T3–L3) spinal cord lesion



ETIOLOGY/PATHOPHYSIOLOGY

- Lumbar spinal cord L1 to L7: dorsolateral section of the ventral gray matter and the location of inhibitory neurons “border cells”
- Border cells are responsible for extensor muscle inhibition of motor neurons in the cervical intumescence; highest concentration of cells are at L2 to L4.



■ **Figure 89.1** Forelimb extensor rigidity and hindlimb paralysis associated with a fracture of the 11th thoracic vertebra.

Systems Affected

- Nervous—Forelimb hypertonia, hindlimb paralysis, and normal cranial nerves
- Musculoskeletal—Non-ambulatory



SIGNALMENT/HISTORY

- Dogs
- Rarely in cats

Historical Findings

- Trauma—hit by car most common
- If unknown trauma—acute paralysis



CLINICAL FEATURES

- Non-ambulatory
- Forelimb extensor rigidity
- Hindlimb paralysis
- Palpation of vertebral column trauma
- Often other signs of trauma
- Cranial nerves are normal
- Forelimbs—rigid extensor tone, normal gait, and postural reactions but “stiff”
- Hindlimbs—paralysis
- Caudal to the lesion—reflexes are normal
- Level of the lesion—cutaneous trunci reflex cutoff; line is often caudal to the lesion by one to two spinal cord segments



DIFFERENTIAL DIAGNOSIS

- Spinal shock
- Cervical spinal cord lesion—other forelimb neurologic deficits besides hypertonia

- Decerebrate rigidity—hypertonia in forelimbs and hindlimbs, unconscious
- Decerebellate rigidity—forelimb hypertonia, hindlimbs flexed, altered mentation



DIAGNOSTICS

- Radiographs, myelography, CT, or MRI to detect spinal cord lesion



THERAPEUTICS

- The objective is immediate spinal cord stabilization to prevent additional trauma during diagnosis and stabilization of concurrent problems.
- The use of glucocorticosteroids is controversial.
- See specific spinal cord diseases for further treatments.



COMMENTS

Client Education

- Posture may remain for several weeks, not an indication of prognosis

Patient Monitoring

- Neurologic examination every 1 to 2 hours for change

Expected Course and Prognosis

- Schiff-Sherrington does not change the prognosis; prognosis and clinical course should be based on the cause of the phenomenon.
- Grave prognosis if deep pain is absent after 48 hours

Abbreviations

- CT: computed tomography
- MRI: magnetic resonance imaging

Suggested Reading

De Lahunta, A. *Veterinary Neuroanatomy and Clinical Neurology*, 2nd ed. Philadelphia: W.B. Saunders Co, 1983.

Smith, PM, and Jeffery, ND. Spinal shock—Comparative aspects and clinical relevance. *J Vet Intern Med* 2005;19:788–793.

Author: Stacy D. Meola

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Mary O. Smith

Scleral and Corneal Lacerations



DEFINITION/OVERVIEW

- Corneal or scleral lacerations are the result of disruption of the corneal or scleral tissue, by blunt or sharp trauma, or by the presence of a foreign body.
- They may be partial or full thickness in nature, and they may or may not involve other intraocular tissues or structures, such as the anterior or posterior uvea, lens, vitreous, or retina.



ETIOLOGY/PATHOPHYSIOLOGY

- Sharp trauma leads to partial or full-thickness disruption of the sclera or cornea and is initiated at the surface of the globe.
- Blunt trauma usually leads to sudden, more severe damage to the intraocular structures, and can lead to blow-out type wounds to the sclera or cornea.

Systems Affected

- Ophthalmic—There may be little to no scarring of the sclera or cornea that would have no significant impact on vision, or the trauma may lead to glaucoma or phthisis bulbi and therefore blindness if the intraocular structures are significantly involved. Collateral damage to the eyelids and the nictitating membrane may also need to be addressed.
- Musculoskeletal—Depending on the degree of the trauma, orbital or skull bones may be damaged, along with extraocular and other nearby muscles. Extraocular muscle damage may lead to strabismus.
- Nervous—Innervation of the cornea, eyelids, iris, extraocular muscles, and lacrimal gland, function of the optic nerve, its radiations, and the visual cortex of the brain may be affected.



SIGNALMENT/HISTORY

- Dogs or cats, no age, breed or sex predilection.

Risk Factors/Causes

- Highly excitable animals
- Spending time in heavy, dry vegetation
- Fighting
- Facial nerve paresis/paralysis
- Lagophthalmos
- Exophthalmos

Historical Findings

- Acute onset
- Possibly in heavy or dry vegetation
- Possibly hit by projectile (rock, pellet, etc.)
- Possibly in altercation with a cat
- Trauma often not observed



CLINICAL FEATURES

- Variable
- Scleral wound may not be visible beneath abnormal conjunctiva (i.e., chemosis, hyperemia, or subconjunctival hemorrhage).
- Uveal tissue may be prolapsed through wound.
- Corneal wound may appear open, closed, or sealed with fibrin or uveal tissue.
- Foreign body may or may not be present.
- Corneal edema, dyscoria, hyphema, cataract, vitreal hemorrhage, retinal detachment, or exophthalmia may be present.



DIFFERENTIAL DIAGNOSIS

- Identification of wound is diagnostic. If no wound is found, then one must consider traumatic incident without laceration.
- Sometimes underlying disease seems to become apparent to the owner “overnight,” when disease has been present for weeks or months but has not been identifiable until now. Occasionally infectious disease, immune-mediated disease or neoplasia will present in this manner.



DIAGNOSTICS

- Identify tissues involved and possible cause and nature of damage to the eye.
- Be very careful to not put pressure on the globe until rupture or laceration has been ruled out.

- Perform as complete an ophthalmic examination as possible, including Seidel test when indicated. Be sure to examine periocular skin and orbit.
- Consider scleral rupture when subconjunctival hemorrhage is present, shallow or deep anterior chamber is present, vitreal hemorrhage is present, or the globe is very soft.
- Blood work and urinalysis are usually not helpful if just the eye is affected. These should be considered if general anesthesia is required, or if another underlying disease process is suspected.
- Consider cytology or culture and sensitivity of wound.
- Consider coagulation profile if bleeding cannot be explained due to trauma.
- Imaging such as ocular ultrasound, orbital radiographs, CT or MRI should be considered to ascertain extent of damage and possibly identify foreign body.

Pathologic Findings

- Depend on extent of ocular damage
- Posttraumatic sarcoma occurs in cats. May be months or years after initial trauma.



THERAPEUTICS

Drug(s) of Choice

- Note: medications that would otherwise be impervious to the eye due to blood-eye barriers will likely enter the acutely inflamed eye. Inflammation reduces the effectiveness of these barriers and allows larger molecules to leave the bloodstream.

Antibiotics

- Penetrating wounds, but nonperforating and uncomplicated: topical antibiotics alone (neomycin and polymyxin B and bacitracin, or tobramycin) are usually adequate.
- Perforating wounds with negative Seidel test: systemic antibiotics (dogs, enrofloxacin 10 to 20 mg/kg PO once daily, cephalexin 11 to 22 mg/kg three times daily; cats, amoxicillin-clavulanic acid 13.75 mg/kg twice daily); topical antibiotics (for good penetration, fluoroquinolones such as ofloxacin, gatifloxacin, or moxifloxacin) 1 gtt every 1 to 6 hours.
- Perforating wounds with positive Seidel test: same as for perforating wounds with negative Seidel test, only after wound has been sealed.

Anti-Inflammatories

- If no infection is present, topical prednisolone acetate 1% or 0.1% dexamethasone suspensions every 6 to 12 hours; systemic prednisone 0.5 to 1.0 mg/kg once to twice daily.
- NSAIDs; topical (flurbiprofen or diclofenac 1 gtt every 8–12 hours); systemic (dogs, carprofen 2.2 mg/kg PO twice daily or firocoxib 5 mg/kg PO every 24 hours).

- Only if inflammation cannot be controlled with systemic anti-inflammatories and there is significant risk of vision loss if present inflammation is not controlled.

Mydriatics

- Atropine 1% ophthalmic solution every 6 to 12 hours when there is significant miosis or aqueous flare. Frequency may be decreased as long as pupil remains dilated.

Analgesics

- Topical atropine—see previous information
- Systemic anti-inflammatories—see previous information
- Butorphanol—dogs, 0.2 to 0.4 mg/kg; cats, 0.1 to 0.2 mg/kg IV, SQ, or IM every 2 to 4 hours or as needed for mild pain.
- Oxymorphone—dogs, 0.05 to 0.1 mg/kg; cats, 0.05 mg/kg IV, SQ, or IM every 4 to 6 hours or as needed for severe pain where sedation is required.
- Naloxone—0.04 mg/kg IV, SQ, or IM to reverse narcotics.

Precautions/Interactions

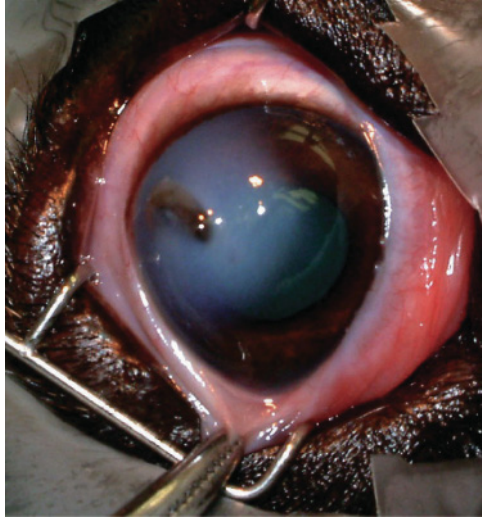
- Avoid ophthalmic ointments in cases where perforation has occurred. If ointment gets inside the eye, it will likely lead to granulomatous inflammation.
- Avoid systemic enrofloxacin and orbifloxacin in young dogs, risk of disruption of cartilage synthesis.
- Enrofloxacin in cats may lead to acute retinal degeneration and vision loss.
- Aminoglycosides—if used frequently or at high concentrations they may be irritating and may impede re-epithelialization; may need to carefully calculate dose in very small animals, especially if giving this kind of drug systemically as well.
- Topical steroidal and nonsteroidal anti-inflammatories may delay wound healing.
- Atropine may exacerbate KCS and glaucoma.
- Safety of topical nonsteroidal anti-inflammatories in cats has not been determined.
- Systemic NSAIDs may potentiate nephrotoxicity of aminoglycosides; be sure animal is well hydrated and kidney function is adequate.

Alternative Drugs

- Compounding fortified and noncommercial topical antibiotic solutions is possible with cefazolin, gentamicin, tobramycin, and others. More aggressive therapy is achieved by increasing the concentration in some of these solutions.

Activity

- Should be confined to indoors or small, well controlled environment. Cats should remain indoors. Leash walking usually okay. Consider using a harness to keep pressure off neck and avoid increasing intraocular pressure.



■ **Figure 90.1** Full-thickness corneal laceration in a boxer puppy after an altercation with a cat 20 hours prior to presentation. The iris has prolapsed through the corneal defect and has sealed the laceration such that aqueous humor is no longer leaking from the eye. There is also localized corneal edema.

Surgical Considerations

Injuries Possibly Requiring Surgery

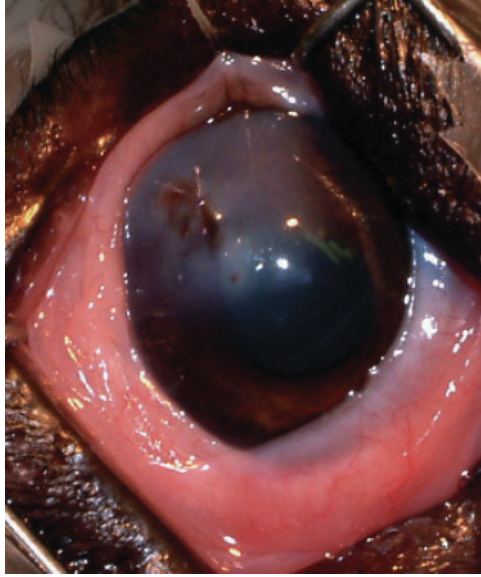
- Small, full-thickness corneal laceration that has sealed and has no uveal prolapsed (Figures 90.1, 90.2, 90.3)
- Nonperforating wound with moderate to severe gaping
- Nonperforating wound that is deeper than two-thirds corneal thickness

Injuries Requiring Surgery

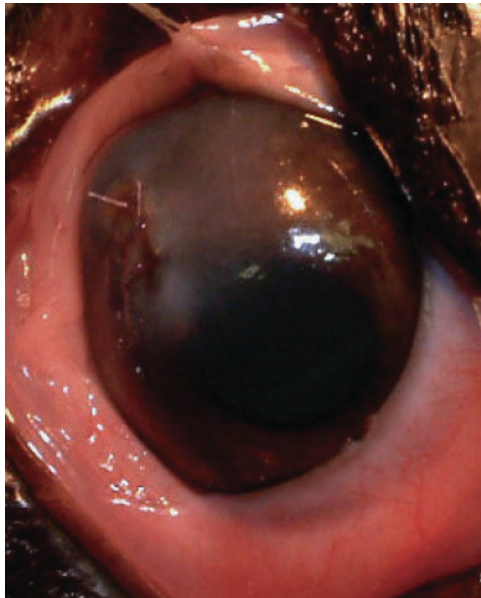
- Full-thickness sclera or corneoscleral lacerations, with or without positive Seidel test
- Full-thickness wounds with uveal prolapse
- Possible retained foreign body
- Possible posterior scleral rupture

Injuries Requiring Medical Management

- Nonperforating wounds with little to no wound gaping
 - Treat with topical antibiotics and possibly atropine. Systemic NSAIDs or steroidal anti-inflammatories may be helpful as well. Apply an Elizabethan collar.
 - Recheck examination in 3 to 5 days to make sure condition is not deteriorating.
- Uncomplicated, full-thickness, punctate corneal wounds that have sealed and have no uveal prolapse.
 - Treat with topical antibiotics (fluoroquinolones recommended) and possibly atropine. If the globe has been penetrated, systemic antibiotics should be considered.



■ **Figure 90.2** The iris tissue has been repositioned and is being held in place with one 8-0 simple interrupted suture.



■ **Figure 90.3** Corneal laceration immediately following surgical repair with 3 interrupted 8-0 polyglactin 910 sutures.

Systemic nonsteroidal or steroidal anti-inflammatories may be helpful as well. Apply an Elizabethan collar.

- Recheck in 1 to 2 days to make sure condition is not deteriorating.



COMMENTS

Client Education

- Warn owners that full extent of ocular damage (i.e., cataracts, lens capsule rupture, retinal detachment, glaucoma, or infection) may not be apparent for days or weeks after initial injury.
- With ocular disease, prognosis for vision and prognosis for keeping the globe and remaining comfortable must both be discussed.

Patient Monitoring

- Deep or perforating wound should be checked every 24 to 48 hours to monitor for infection, control of inflammation, and structural integrity of the globe.
- Superficial wounds should be rechecked every 3 to 5 days until adequate healing has occurred.

Prevention/Avoidance

- Carefully introduce new dogs, especially puppies, to new cats with front claws.
- Dogs that like to venture into thick vegetation, especially those that are low to the ground, and especially those with significant ocular exposure (i.e., brachiocephalic breeds) are at more risk of injury. Dogs with vision impairment or blind dogs should be monitored in these conditions as well.

Possible Complications

- Loss of vision
- Chronic ocular inflammation or pain necessitating removal of the globe
- Posttraumatic sarcoma in cats

Expected Course and Prognosis

- Most corneal lacerations and foreign bodies can be successfully treated.
- Injuries that have a poorer prognosis are those with posterior uveal involvement, lack of light perception in the injured eye, lens involvement, moderate-to-severe vitreal hemorrhage, or retinal detachment.
- An eye that sustains blunt trauma usually has a poorer prognosis than one that experiences sharp trauma.

Abbreviations

- CT: computed tomography

- IM: intramuscularly
- IV: intravenously
- KCS: keratoconjunctivitis sicca
- MRI: magnetic resonance imaging
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Gelatt, KN, and Gelatt, JP. *Small Animal Ophthalmic Surgery: Practical Techniques for the Veterinarian*.

Edinburgh: Butterworth and Heinemann, 2001.

Maggs, DJ. Cornea and sclera. In: Maggs, DJ, Miller, PE, and Ofri, R, eds. *Slatter's Fundamentals of Veterinary Ophthalmology*, 4th ed., pp. 260–313. St. Louis: Saunders, 2008.

Severin, GA. *Severin's Veterinary Ophthalmology Notes*, 3rd ed. Fort Collins, CO: DesignPoint Communications Inc., 1996.

Author: Bradley P. Graham

Seizures



DEFINITION/OVERVIEW

- A seizure is a nonvolitional, unregulated, rhythmic, repetitive excitatory discharge of neurons in the cerebral cortex.
- Seizures can be focal or generalized, convulsive, or nonconvulsive (i.e., lacking gross movement).
- Focal seizures may manifest themselves as repetitive, uncontrolled tonic-clonic movement of a single area of the body such as the jaw or a single limb.
- Seizures can begin focally and become generalized as more neurons in the cerebral cortex become excited.
- Generalized seizures usually are characterized by tonic-clonic movement of the entire body.
- The term *cluster seizures* refers to more than two seizures in a 24-hour period.
- Status epilepticus is seizure activity that lasts longer than 5 minutes or 30 minutes of seizure activity with incomplete recovery.



ETIOLOGY/PATHOPHYSIOLOGY

- Seizures may result from extracranial (reactive) and intracranial (symptomatic) etiologies.
- Extracranial causes of seizures are systemic disorders that result in the exposure of brain cells to epileptogenic substances or conditions.
 - Extracranial etiologies include: toxins, electrolyte imbalances (i.e., hypocalcemia, hypomagnesemia, hypophosphatemia, disturbances in sodium), hypoglycemia, uremic encephalopathy, hepatic encephalopathy, energy deprivation, and endocrinopathy.
- Intracranial causes of seizures result from structural derangement of the cerebral cortex.
 - Intracranial etiologies include: tumors (primary or metastatic), encephalitis (infectious and non-infectious), malformations (e.g., hydrocephalus), degenerative brain disease, vascular disorders, and idiopathic epilepsy.

Systems Affected

- Cardiovascular—possible arrhythmias.

- Endocrine/Metabolic—lactic acidosis, dehydration, hyperthermia.
- Nervous
- Respiratory—neurogenic pulmonary edema, possible respiratory distress or airway obstruction during seizure event.



SIGNALMENT/HISTORY

- Age, sex, and breed predisposition will vary according to the underlying etiology that leads to seizures.
- Younger (1–5 year old), large breed, male dogs are commonly diagnosed with idiopathic epilepsy.
- Idiopathic epilepsy is poorly characterized in cats.
- Idiopathic epilepsy appears to be a heritable disease in breeds such as the Labrador retriever, German shepherd, Vizla, Finnish Spitz, and Dachshund.
- Small breed dogs, especially those with dome shaped heads, are frequently affected by malformations like hydrocephalus or Chiari-like malformation that may result in seizures.
- Older dogs and cats are more likely than younger animals to have intracranial neoplasia; some tumor types, such as meningioma, may have breed and sex predilections.
- Animals of any age and breed can be affected by toxins, metabolic disorders, organ dysfunction, and encephalitis.
- Seizures (the ictus) are usually typified by: a loss of consciousness, body/limb convulsions, and autonomic activity (i.e., tachycardia, salivation, urination, defecation).
- Animals that have seizures may have preictal behavioral changes, sometimes called an *aura*.
- Postictal neurological signs are exceedingly common regardless of etiology and may include blindness, mentation changes, and ataxia; typically, postictal deficits will resolve within hours or a few days and will very likely be symmetrical if the underlying etiology is extracranial.

Risk Factors/Causes

- Risk factors are dependent on the etiology leading to seizure activity.
- In general, animals with structural disease involving the forebrain are predisposed to developing seizures.
- Extracranial seizures may be precipitated by exposure to toxins, medications, systemic diseases of the liver and kidney, as well as diseases that alter electrolytes (e.g., Addison's disease) or result in hypoglycemia (e.g., insulinoma).

Historical Findings

- Owners may report an aura; the animal may hide, whine, seek attention, or appear restless prior to the ictus.

- During the postictal period, the animal may appear blind, walk into walls, circle, show ataxia, be non-ambulatory, or have mentation changes.
- The animal should lose consciousness during a generalized seizure and be unresponsive to the owner. Tonic-clonic movements are commonly noted.
- The owner may report finding feces and urine in the house that were produced during an unrecognized seizure event.



CLINICAL FEATURES

- Animals may have completely normal physical examinations or may show abnormalities that reflect underlying systemic disease, recent seizure activity (e.g., postictal signs, hyperthermia) or neurologic examination findings suggesting structural disease.
- Abnormal neurologic examination findings include altered mentation, obtundation or coma, evidence of cortical blindness, circling, and postural reaction deficits.
- The neurologic examination abnormalities may disappear with time if they are postictal or remain if they are a result of structural intracranial disease.
- Postictal deficits are typically symmetrical if the underlying etiology is not structural derangement of the central nervous system.



DIFFERENTIAL DIAGNOSIS

- Syncope—Syncope is defined as a loss of consciousness secondary to lack of adequate blood flow to the brain, which is usually sudden in onset and of short duration.
 - Owner history is important in differentiating syncope from seizures.
 - Syncopal episodes usually are preceded by excitement or exercise and can range in severity from rear limb weakness to total collapse.
 - Recovery from syncopal episodes is usually rapid with no lingering deficits.
 - Animals suspected of syncope should have a complete cardiac evaluation.
- Narcolepsy is characterized by sudden onset REM sleep, cataplexy, sleep hallucinations, excessive daytime sleepiness, and sleep paralysis.
 - Episodes are usually preceded by an excitatory stimulus such as feeding or seeing an intact member of the opposite sex.
 - The Labrador retriever and Doberman pinscher are predisposed and have an autosomal recessive pattern of inheritance.
- Acute fulminant neuromuscular diseases, such as myasthenia gravis and congenital myotonia, may be mistaken for seizures.
 - Owners may describe the collapse and weakness associated with myasthenia gravis as a seizure.
 - Animals with congenital myotonia will demonstrate a sudden onset of generalized spasticity and collapse, with resolution after a few minutes.

- Acute vestibular attack—Vestibular diseases (especially those that are idiopathic or vascular) can have a sudden onset of clinical signs.
 - Affected animals may roll around and be unable to rise, which may be mistaken for a seizure.



DIAGNOSTICS

- A CBC, chemistry panel with electrolytes, coagulation profile, and urinalysis should be performed on all animals with seizures.
- Bile acid testing or a random ammonia level may be helpful in animals suspected of having liver disease based on clinical signs, signalment, or chemistry values (i.e., low albumin, low cholesterol, low BUN, low glucose, abnormal liver enzymes).
- If the animal is currently on anti-epileptic medications, serum should be drawn for blood drug levels prior to administration of AEDs other than diazepam.
- Blood pressure monitoring and pulse oximetry are encouraged, especially in animals with recent severe seizure events or those exhibiting respiratory distress.
- Imaging and CSF examination should always be recommended for seizing animals without an etiologic diagnosis, unless there is clear evidence for a metabolic or toxic cause for seizures.
- MRI is the preferred imaging modality, although CT can also be helpful because many forebrain lesions would be visible, even as subtle changes.
- As long as there is no evidence of increased intracranial pressure (i.e., severe midline shift, brain herniation, obstructive hydrocephalus) or definitive neoplastic lesions on imaging, CSF collection can be performed.

Pathological Findings

- Gross and histopathologic findings will vary based on the cause of the seizures.
- Prolonged seizures of any cause can result in edema and neuronal necrosis, especially in the hippocampus and temporal lobes.



THERAPEUTICS

- The first objective of treatment is to stop ongoing seizure activity and to prevent future seizure activity.
- A rapid acting AED should be administered to all patients actively having a seizure at the time of admission.
- If serum biochemistry suggests an underlying metabolic etiology such as hypoglycemia or hypocalcemia, this should be corrected. Treatment of an animal with maintenance AEDs should be pursued if the patient presents in status epilepticus or has at least two seizures in a 24-hour period.
- If seizures resulted from intoxication or metabolic disease that is resolved, maintenance AEDs can be tapered over a few weeks.

- Animals with structural intracranial disease, idiopathic epilepsy, or unresolved metabolic disease will need to be continued on a maintenance AED, unless the underlying cause of seizures can be definitively treated.

Drug(s) of Choice

Emergency

- Patients that are actively seizing should receive an intravenous bolus of diazepam at a dose of 0.5 mg/kg if they are not on AEDs and 1 mg/kg if they are currently receiving AEDs that are p450 inducers, such as phenobarbital.
- These doses are doubled for rectal administration in cases where intravenous access is not immediately available.
- Midazolam can be used as an alternative to diazepam.
- Dogs that are unresponsive or partially responsive to diazepam will require additional AED treatment.
- Typically, phenobarbital is the next drug used and can be loaded IV.
- Propofol or other rapid acting AEDs may need to be used while waiting for phenobarbital to take effect.
- Recently, newer AEDs, such as levetiracetam, have become available as intravenous preparations and are likely safe alternative in dogs and cats.
- The following is a brief list of emergency drugs.

Diazepam

- Mechanism: GABA receptor agonist (hepatic elimination).
- Adverse effects: Sedation, excitement, hepatopathy (cats after oral use).
- Dosage: 0.5 mg/kg (1 mg/kg in animals on phenobarbital) IV as a bolus; CRI 0.2 to 2 mg/kg per hour (0.2–0.5 mg/kg per hour typical starting range); rectal (double intravenous bolus dosage).
- Animals on a diazepam CRI or receiving boluses without correctable metabolic disturbances will need a maintenance drug to prevent seizure activity.
- Animals on a diazepam CRI will need to be weaned off.

Midazolam

- Mechanism and adverse effects: similar to diazepam
- Dosage: 0.1 to 0.3 mg/kg IV, IM, SQ

Phenobarbital

- Mechanism: GABA receptor agonist with 24- to 72-hour half-life (hepatic elimination).
- Adverse effects: Polyuria, polydipsia, polyphagia, behavioral alteration, hepatopathy (especially at blood level >35–40 µg/mL), bone marrow dyscrasia (usually within 1 month of initiating therapy), dermatopathy, movement disorders, low thyroid hormone levels.
- Cardiopulmonary depression and hypotension if given IV at high doses.

- Dosage: Load at 12 to 16 mg/kg.
- In relatively stable animals 6 mg/kg intravenous bolus is followed by the remainder of the load divided over 24 hours.
- May take up to 20 minutes for full effect IV, so other drugs may need to be used while an animal that is actively convulsing is being loaded.
- In cases of intractable seizures up to 30 mg/kg can be administered in a day with single bolus loads up to 16 mg/kg.

Alternative Drugs

Propofol

- Mechanism: Novel hypnotic (hepatic and systemic microsomal elimination).
- Adverse effects: Sedation, cardiopulmonary depression, hypotension, Heinz body formation (cats with sustained exposure).
- Dosage: 2 to 8 mg/kg bolus; CRI 0.1 to 0.6 mg/kg per minute.

Pentobarbital

- Dose of 1 to 3 mg/kg bolus followed by repeated boluses or 3 to 10 mg/kg per hour CRI.
- Although pentobarbital may reduce convulsive activity, some authors have questioned its ability to inhibit the neuronal firing associated with seizures.
- Pentobarbital is not recommended by the authors of this chapter.

Other Alternatives

- Levetiracetam is an effective AED and is available in an intravenous preparation.
- Anesthesia may also be induced and maintained on isoflourane or with a propofol or phenobarbital CRI.
- These animals will require intubation and will need ventilatory support.

Maintenance Therapy

- Maintenance AED therapy in veterinary medicine is rapidly evolving.
- Although many authors consider traditional drugs such as phenobarbital and potassium bromide as the “drugs of choice,” other authors prefer costlier, newer drugs that have fewer reported side effects, less rigorous monitoring requirements, and likely have equal or greater efficacy compared to traditional options.
- Potassium bromide is not an acceptable maintenance AED in cats because of adverse pulmonary effects.
- Diazepam has been used as a maintenance drug in cats, although most authors discourage this because severe, irreversible hepatopathy has been described.
- Some animals will not be controlled with single maintenance AEDs and may require bi- or trimodal therapy.
- For traditional drugs please make certain that blood drug levels are in appropriate range before adding additional medications.
- Some newer drugs are dosed to effect.

Newer Drugs

Zonisamide (Zonegran)

- Mechanism: Blockade of calcium and sodium channels; enhanced GABA release. It has a 15-hour half-life.
- Hepatic metabolism
- Adverse effects: Ataxia, vomiting, lethargy, keratoconjunctivitis sicca
- Follow up: CBC and biochemistry every 6 months
- Zonisamide blood levels are not widely available.
- Dosage: 4 to 10 mg/kg PO twice a day in dogs
- If this drug is being used in combination with drugs inducing hepatic microsomal enzymes, the higher end of the dose range may be required.
- Not suggested in cats

Levetiracetam (Keppra)

- Mechanism: Calcium and glycine channel blockade
- Half-life of 4 hours in dog, although significant effect occurs during trough
- Urinary elimination with extrahepatic hydrolysis
- Adverse effects: believed to be extremely safe
- Ataxia, salivation, and gastrointestinal signs are seen with extremely high doses.
- Follow up: CBC and biochemistry are suggested every 6 months.
- Levetiracetam levels are not widely available and are of questionable value.
- Dosage: 20 mg/kg PO three times a day starting dose in dogs
- Can be increased in 10 to 20 mg/kg increments
- Can be provided IV as a 20 mg/kg slow bolus
- Similar dosing has been attempted in cats.

Gabapentin (Neurontin)

- Mechanism: Increased synthetic GABA levels, calcium channel blockade
- Renal (major route) and hepatic metabolism
- Half-life is 3 to 4 hours in dog, although significant effect occurs during trough.
- Adverse effects: Mild ataxia and sedation
- Follow up: Gabapentin levels are not widely available and are of questionable value in human medicine.
- Dosage: 30 to 60 mg/kg/day divided three to four times daily in dogs
- 5 to 10 mg/kg PO two to three times daily in cats
- Do not use liquid gabapentin that contains xylitol.

Traditional Drugs

Phenobarbital

- Follow up: Blood drug levels should be obtained 14 to 21 days after altering dosage or if seizures are poorly controlled.

- When starting dogs on phenobarbital, a CBC, biochemistry, and bile acid test are suggested.
- Rechecking chemistry panels, phenobarbital levels, and bile acid values every 6 months is suggested.
- Dosage: Starting dose 2 to 3 mg/kg PO twice daily in dog with incremental adjustment if seizures are poorly regulated.
- Therapeutic levels are believed to be between 15 µg/ml and 35 µg/ml in most dogs and between 15 µg/ml and 30 µg/ml in most cats.

Potassium Bromide

- Mechanism: GABA receptor agonist with 20- to 30-day half-life (renal elimination).
- Adverse effects: Polyuria, polydipsia, polyphagia, gastrointestinal disease, behavioral alteration, pancreatitis, dermatopathy, ataxia (especially pelvic limb), and false elevation of chloride on blood chemistry.
- Contraindicated in cats due to potentially fatal pneumonitis; relatively contraindicated in animals with nephropathy and cardiac disease.
- Follow up: Blood drug levels are obtained 3 months after initiating therapy or changing therapy.
- Chemistry, urinalysis, and blood bromide levels are suggested every 6 months to 1 year.
- Diet change should be discouraged, if possible, as alteration in salt content can change blood drug levels.
- Dosage: Naïve animals should be orally loaded at 100 mg/kg every 24 hours for 5 days.
- In emergency situations the total load can be given over one day and may be administered rectally, although gastrointestinal signs are frequent.
- Maintenance dosing is 30 to 40 mg/kg PO every 24 hours.
- When doses are increased, a partial load (100 mg/kg and new dose/day for 5 days) is suggested.
- Diuresis with 0.9% saline will rapidly lower blood levels.
- Therapeutic drug levels range between 1 and 3 mg/ml.

Precautions/Interactions

- AEDs are complex drugs, and any precautions or interactions listed represent only a small proportion of those possible.
- In general, acepromazine has questionable pro-epileptogenic properties and some practitioners feel it should be used cautiously in dogs with seizures.
- Drugs that lower the seizure threshold should be avoided if possible.
- Animals on phenobarbital may have altered or increased metabolism of other drugs eliminated by the cytochrome p450 pathway in the liver.

Diet

- The animal's diet should not be changed without cause if the patient is receiving potassium bromide as different salt content of food can affect drug absorption.
- Animals on potassium bromide should also have a drug level checked 2 to 3 months after a change in the mineral composition of water.
- Diet may also affect blood phenobarbital level.
- Ketogenic diets, while effective in juvenile humans to reduce seizure frequency, do not work well in veterinary species.

Activity

- No alterations in activity are suggested.

Surgical Considerations

- Animals with central nervous system disease are at increased risk for anesthetic complications.
- Monitoring of end-tidal carbon dioxide, blood pressure, heart rate, and other parameters is recommended during anesthesia because brain herniation can be a sequela of anesthesia; signs of this could include Cushing's reflex (hypertension with bradycardia), anisocoria, miosis, or unresponsive pupils.
- Surgical therapy for certain structural central nervous system diseases can be attempted.
- Surgical resection of an epileptic focus is not typically performed in veterinary medicine.



COMMENTS

Client Education

- Clients need to understand that treatment will be lifelong and will require monitoring of the patient in animals with idiopathic epilepsy or underlying structural intracranial disease.
- The client should be instructed to maintain a seizure diary for the patient.
- Regular dosing of the AED needs to be emphasized as well as the negative consequences of sudden cessation of medication.

Patient Monitoring

- While hospitalized, animals should be under near constant observation for seizure activity.
- Some facilities will attach bells to animals in an effort to help alert staff to a seizure event.

- The frequency of seizures should be monitored by the owner; more than one seizure per month indicates the need for blood drug levels or a change in drug dosage.
- See other monitoring under specific AEDs.

Prevention/Avoidance

- Some owners report that certain activities can trigger seizures in their pets; these activities should obviously be avoided if such a link is suspected.

Possible Complications

- Patients who are seemingly well-regulated for a period of time may develop breakthrough seizure activity and need medication adjustments.
- Prolonged seizures or cluster seizures can be life threatening because they may place increased metabolic demands on the patient and interfere with energy delivery to cells.
- Patients that have breakthrough seizure activity that is untreated will likely be at risk for the expansion of their epileptic focus, which may make seizure control more challenging.

Expected Course and Prognosis

- The course and prognosis associated with seizures are variable and depend on the underlying etiology.
- Idiopathic epileptics have a good prognosis, although the expense of drugs and therapeutic monitoring can be daunting for some owners.
- Some animals with idiopathic epilepsy will require therapy with multiple AEDs or may have to be switched to more expensive medications as a result of side effects.
- Animals with encephalitis have a variable prognosis ranging from guarded to excellent depending on the etiology.
- Animals with brain tumors have a poor prognosis without treatment and a fair prognosis and increased survival with radiation therapy or surgery.
- The prognoses of animals with organ dysfunction or toxicities will vary depending on the severity of the disease.

Synonyms

- Epilepsy

Abbreviations

- AED: anti-epileptic drug
- BUN: blood urea nitrogen
- CBC: complete blood count
- CRI: constant rate infusion
- CSF: cerebrospinal fluid
- CT: computed tomography

- GABA: gamma-amino-butyric acid
- IM: intramuscularly
- IV: intravenously
- MRI: magnetic resonance imaging
- PO: by mouth
- REM: rapid eye movement
- SQ: subcutaneously

Suggested Reading

- Dewey, CW. Anticonvulsant therapy in dogs and cats. *Vet Clin North Am Small Anim Pract* 2006;36:1107–1127.
- Kline, KL. Feline epilepsy. *Clin Tech Sm Anim Pract* 1998;13:152–158.
- Knowles, K. Idiopathic epilepsy. *Clin Tech Sm Anim Pract* 1998;13:144–151.
- Platt, SR, Adams, V, Garosi, LS, et al. Treatment with gabapentin of 11 dogs with refractory idiopathic epilepsy. *Vet Rec* 2006;159:881–884.
- Von Klopman, T, Rambeck, B, and Tipold, A. Prospective study of zonisamide therapy for refractory idiopathic epilepsy in dogs. *J Small Anim Pract* 2007;48:134–138.

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Acknowledgment to original authors in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Andree D. Quesnell and Joane M. Parent

Serotonin Syndrome



DEFINITION/OVERVIEW

- Serotonin syndrome is a complex of clinical signs resulting from overstimulation of serotonin receptors in the central and peripheral nervous systems.
- In humans, serotonin syndrome is defined as a combination of symptoms that includes at least three of the following: myoclonus, mental aberration (dementia, disorientation, etc.), agitation, hyperreflexia, tremors, diarrhea, ataxia, or hyperthermia.



ETIOLOGY/PATHOPHYSIOLOGY

- Serotonin syndrome is caused by excessive stimulation of serotonin receptors. This most commonly occurs in pets following inappropriate ingestion of pharmaceuticals. Such pharmaceuticals can include drugs that enhance serotonin synthesis (i.e., L-tryptophan, L-5-hydroxytryptophan), drugs that increase presynaptic serotonin release (i.e., amphetamines and derivatives, MAOIs, cocaine), drugs that inhibit serotonin uptake into the presynaptic neuron (i.e., SSRIs, TCAs, amphetamines, cocaine, dextromethorphan, meperidine), drugs that inhibit serotonin metabolism (i.e., MAOIs) and drugs that act as serotonin agonists (i.e., buspirone, sumatriptin, LSD) (Table 92.1).

Systems Affected

- Gastrointestinal—increased smooth muscle contractility
- Nervous—stimulation and altered mental status; increased autonomic function
- Cardiovascular—decreased vascular tone, increased cardiac stroke rate and volume
- Neuromuscular—autonomic dysfunction (hyperactivity)
- Respiratory—increased bronchial smooth muscle contraction

TABLE 92.1 Mechanism of Action of Serotoninerbic Drugs

| | |
|------------------------------|---|
| Increase serotonin synthesis | L-tryptophan L-5-hydroxytryptophan (5HTP) |
| Increase serotonin release | Amphetamines Dextroamphetamine and amphetamine (Adderall®) Methamphetamine (Crystal) Methylphenidate (Ritalin®) N-Methyl-3,4-methylenedioxyamphetamine (MDMA, Ecstasy)* Cocaine Dexfenfluramine (Redux®) Fenfluramine (Pondimin®)* Reserpine Dextromethorphan (DXM)* |
| Decrease metabolism | Amphetamine metabolites Monoamine oxidase inhibitors Isocarboxazid (Marplan®) Linezolid (Zyvox®) Moclobemide (Manerix®-Canada) Pargyline (Eutonyl®) Phenelzine (Nardil®)* Selegiline (Eldepryl®, Anipryl®)* Tranylcypromine (Parnate®)* St. John's wort (<i>Hypericum punctatum</i>) |
| Inhibit serotonin uptake | Tricyclic antidepressants Amitriptyline (Elavil®)* Amoxapine (Asendin®) Clomipramine (Anafranil®, Clomicalm®) Desipramine (Norpramin®) Doxepin (Sinequan®, Adapin®) Imipramine (Tofranil®)* Maprotiline (Ludiomil®) Nortriptyline (Pamelor®) Protriptyline (Vivactil®) Trimipramine (Surmontil®) Selective serotonin reuptake inhibitors Citalopram (Celexa®) Escitalopram (Lexapro®) Fluoxetine (Prozac®)* Fluvoxamine (Luvox®) Kanna (<i>Sceletium tortuosum</i>) Paroxetine (Paxil®)* Sertraline (Zoloft®)* Other serotonin uptake inhibitors Amphetamines Cocaine Dextromethorphan Duloxetine (Cymbalta®) Meperidine (Demerol®) Mirtazapine (Remeron®) Nefazodone (Serzone®) Risperidone (Risperdal®) Sibutramine (Meridia®) Tramadol (Ultram®) Trazodone (Desyrel®) Venlafaxine (Effexor®)* |

TABLE 92.1 Continued

| | |
|------------------------------------|--|
| Direct serotonin receptor agonists | Almotriptan (Axert®) Buspirone (Buspar®) Eletriptan (Relpax®) Frovatriptan (Frova®) Lysergic acid diethylamide (LSD) Naratriptan (Amerge®) Rizatriptan (Maxalt®) Sumatriptan (Imitrex®) Zolmitriptan (Zomig®) Phenylalkylamines (mescaline) |
| Dopamine agonists | Amantadine (Symmetrel®) Bromocriptine (Parlodel®) Bupropion (Wellbutrin®) Levodopa (L-dopa) Pergolide (Permax®) Pramipexole (Mirapex®) |
| Nonspecific serotonergic agents | Lithium (Lithobid®, Eskalith®)* |

*High risk of serotonin syndrome.



SIGNALMENT/HISTORY

- No breed, age, or sex predilection.
- Vomiting, diarrhea, seizures, hyperthermia, hyperesthesia, depression, mydriasis, vocalization, agitation, tremors, blindness, hypersalivation, respiratory distress, ataxia/paresis, disorientation, death, hyperreflexia, and coma.

Risk Factors/Causes

- Increased risk in animals with underlying hepatic or renal disease.
- Increased risk of signs if animal is already on a serotonergic drug.

Historical Findings

- Lethargy or agitation, mydriasis, ataxia, tremors, vomiting, diarrhea, hypersalivation, anorexia, seizures, or nystagmus



CLINICAL FEATURES

- Hyperthermia, pale mucous membranes, tachycardia, mydriasis, vomiting, diarrhea, agitation, tremors, hypersalivation, seizures, or nystagmus.



DIFFERENTIAL DIAGNOSIS

- Toxicologic differentials include metaldehyde, lead, antifreeze, hops, anticholinergic, or antihistamine toxicosis.
- Other disease processes such as malignant hyperthermia, heat stroke, meningitis (i.e., rabies, canine distemper, etc.) and neoplasia can cause similar CNS signs.



DIAGNOSTICS

- There are no diagnostic tests to confirm serotonin syndrome.
- Diagnosis is based on history of ingestion of serotonergic drugs and presence of appropriate clinical signs.
- Testing for various pharmaceuticals can be performed, but due to the turnaround time and lack of diagnostic levels in pets this is rarely done.
- Electrolytes, BUN, creatinine, CK, urinalysis, and blood gases; assess metabolic acidosis and rhabdomyolysis.



THERAPEUTICS

- Prevent development of signs or to decrease the severity of signs once they occur by decreasing serotonin levels.

Drug(s) of Choice

- Emesis (if asymptomatic and recent ingestion) or gastric lavage
- Activated charcoal with cathartic (may need to repeat)
- Phenothiazines (acepromazine 0.025–0.05 mg/kg IV, titrate up as needed) or benzodiazepines (diazepam 0.5–2 mg/kg IV) can be used to control agitation.
- Cyproheptadine (dog 1.1 mg/kg, cat 2–4 mg PO every 4–6 hours; may give rectally if vomiting) is a nonselective serotonin antagonist.

Precautions/Interactions

- Contraindicated drugs (high risk of serotonin syndrome): amphetamines, SSRIs, MAOIs, TCAs, hydroxytryptophan, clarithromycin, dextromethorphan, lithium, St. John's wort
- Use with caution (low risk of serotonin syndrome): amantadine, bupropion, carbamazepine, codeine, and tramadol
- Drug interactions: cimetidine (decreased metabolism of serotonergic drugs), class IC antiarrhythmics (propafenone, flecainide [increased cardiac arrhythmias]), metoprolol (bradycardia, hypotension), quinidine (decreased metabolism of serotonergic drugs), and theophylline (increased theophylline levels)

Diet

- NPO as needed with severe CNS signs.

Activity

- Confine until clinical signs resolve.



COMMENTS

Client Education

- No additional or long term problems expected after recovery.

Patient Monitoring

- Heart rate, blood pressure, respirations, and temperature, take hourly at first and then as needed

Prevention/Avoidance

- Prevent access to serotonergic and all other medications.

Possible Complications

- Sequelae include rhabdomyolysis, DIC, and renal failure secondary to myoglobinuria.

Expected Course and Prognosis

- Prognosis is generally good with quick, aggressive therapy and most animals will recover over 12 to 24 hours. More severely affected animals may develop sequelae or die.

Synonyms

- Serotonin toxicosis, serotonin toxidrome, or serotonin storm.

Abbreviations

- BUN: blood urea nitrogen
- CK: creatinine kinase
- CNS: central nervous system
- DIC: disseminated intravascular coagulation
- IV: intravenously
- LSD: d-lysergic acid diethylamide
- MAOI: monoamine oxidase inhibitor

- NPO: nothing by mouth
- PO: by mouth
- SSRI: selective serotonin reuptake inhibitor
- TCA: tricyclic antidepressant

Suggested Reading

DeClementi, C. Prevention and treatment of poisoning: cyproheptadine. In: Gupta, RC, ed. *Veterinary Toxicology Basic and Clinical Principles*, pp. 1149–1151. New York: Elsevier, 2007.

Gwaltney-Brant, SM. Serotonergic drugs. In: Plumlee, KH, ed. *Clinical Veterinary Toxicology*, pp. 290–291. St. Louis: Mosby, 2004.

Gwaltney-Brant, SM, Albrechtsen, JC, and Khan, SA. 5-Hydroxytryptophan toxicosis in dogs: a retrospective study of 21 cases. *J Am Vet Med Assoc* 2000;216(12):1937–1940.

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Shock—Cardiogenic



DEFINITION/OVERVIEW

- Shock is defined as any condition that results in inadequate effective circulating volume and oxygen delivery to the tissues. Shock has been broken down into several classification categories. In any classification scheme, the underlying problem is that the oxygen delivery is not sufficient to meet the oxygen needs of the tissues. This leads to a cellular oxygen and energy debt. It is important to note that although there may be one predominant category that a specific patient falls into, one must consider all of the aspects of each of the categories when formulating a treatment plan. For example, a patient with severe gastrointestinal disease and hemorrhagic diarrhea may initially present in hypovolemic shock, but as the clinical disease progresses, the gastrointestinal blood barrier may become compromised leading to bacterial translocation, systemic septicemia and septic shock. This can then go on to affect the heart and lead to impaired myocardial contractility, thus exhibiting signs of cardiogenic shock. So although the different categories of shock will be presented, care must be taken to approach each patient with an open mind and the realization that the categories may overlap considerably.
- Cardiogenic shock refers to impaired tissue perfusion secondary to decreased cardiac output and diminished stroke volume.
- Distributive shock describes a condition of relative hypovolemia in which there is massive vasodilation resulting in pooling of the circulating blood volume and impaired tissue perfusion and oxygen delivery.



ETIOLOGY/PATHOPHYSIOLOGY

- Cardiogenic shock occurs secondary to anything that results in impaired cardiac output and compromised tissue perfusion.
- DCM is one of the most common causes of cardiac disease in large breed dogs.
 - DCM is characterized by decreased myocardial contractility, with subsequent ventricular dilation in an effort to maintain cardiac output.
 - Tachyarrhythmias are common with DCM.
 - Impairs forward blood flow and results in decreased tissue perfusion.
- DCM is currently one of the least common forms of heart disease in the cat but can still be associated with taurine deficiency.

- DCM in cats can also present as the final stages of hypertrophic or unclassified cardiomyopathy.
- Hypertrophic cardiomyopathy is one of the most common causes of cardiac disease in the cat.
 - In severe cases, the inability of the ventricle to adequately relax during diastole leads to a decrease in cardiac output secondary to insufficient filling. The impaired cardiac output, combined with the congestive heart failure that occurs secondary to the poor relaxation, leads to significant decrease in oxygen delivery to the tissues.
- Pericardial tamponade is a condition in which pressure is placed on the heart from fluid accumulation in the pericardial sac.
 - This pressure prevents the heart from filling appropriately during diastole, and a subsequent decrease in cardiac output. This may occur secondary to hemangiosarcoma (most commonly affecting the right atrial appendage or right atrium), heart base tumors, idiopathic or other neoplasia (lymphosarcoma, mesothelioma, other), right atrial rupture due to chronic valvular disease, or trauma.
- Patients with severe tachy- or bradyarrhythmias may not have adequate diastolic filling time or appropriate heart rate to provide cardiac output, resulting in secondary impaired perfusion of the tissues.
- Severe ventricular outflow or inflow obstruction secondary to neoplasia, thrombus, heartworm, anatomic abnormalities, stenosis, or granulomas.
- Infective endocarditis can result in significant valvular impairment, thrombus formation, or myocardial depression secondary to sepsis.
- Sepsis induced myocardial depression is characterized by impaired contractility that leads to decreased cardiac output and potentially congestive heart failure.
- The compensatory responses of the body in cases of impaired cardiac output include tachycardia, peripheral vasoconstriction, and activation of the renin-angiotensin-aldosterone system. These compensatory responses increase the work of the heart and can further exacerbate the decrease in tissue perfusion.

Systems Affected

- Cardiovascular—The primary or secondary cardiac disease associated with cardiogenic shock is the cause of the impaired cardiac output. Decreased coronary blood flow further exacerbates the myocardial hypoperfusion and dysfunction and can lead to myocardial ischemia, dysrhythmias, and thrombi formation.
- Pulmonary—Congestive heart failure and associated pulmonary edema are common in patients with cardiogenic shock. This decrease in the ability of the patient to oxygenate and subsequent hypoxia further amplify the decreased tissue perfusion.
- Renal—When the mean arterial blood pressure decreases below 60 mm Hg, the kidneys are no longer able to autoregulate and hypotension directly impairs the blood flow and oxygen delivery. The kidneys normally receive 20 to 25 percent of the cardiac output, and when this is decreased the kidneys are extremely sensitive to

impaired perfusion. This decrease in perfusion may result in renal ischemia and acute tubular necrosis, renal failure and oliguria.

- **Gastrointestinal**—Impaired splanchnic perfusion, and decreased oxygen delivery can result in significant damage to the mucosa, ulceration, the loss of the intestinal blood barrier and subsequent bacterial translocation, intestinal necrosis, and hemorrhage.
- **Hepatic**—Decreased cardiac output results in decreased hepatic blood flow and hepatic congestion. Can lead to hepatic ischemia and impaired hepatic function including decreased gluconeogenesis and subsequent hypoglycemia, decreased clotting factor production, decreased protein synthesis, and hyperbilirubinemia.
- **Nervous**—Central nervous system dysfunction is a significant complication in patients with inadequate oxygen delivery. Coagulation abnormalities associated with cardiogenic shock can lead to vascular events (thrombosis or hemorrhage) that affect the central nervous system. This can result in cerebral ischemia and associated manifestations such as stupor, blindness, and decreased spinal reflexes. The permanence of these neurologic abnormalities is again related to the severity and duration of the shock event.
- **Musculoskeletal**—Musculoskeletal weakness is a common complication in patients with decreased perfusion and oxygen delivery. Musculoskeletal weakness may be profound, and patients should not be stressed until their perfusion is improved. In patients with a dynamic inflow or outflow obstruction, this weakness may be more pronounced when the patients has an increase in activity.



SIGNALMENT/HISTORY

- There is no age, breed, or sex predilection for cardiogenic shock, and it can occur at any age.

Risk Factors/Causes

- Pre-existing cardiac disease, particularly DCM.
- Severe systemic disease associated with a high risk of sepsis.

Historical Findings

- Variable pending the underlying cause of the cardiogenic shock
- A previous history of cardiac disease (murmur, dysrhythmia)
- Collapse, syncope, possibly associated with activity
- Respiratory distress



CLINICAL FEATURES

- Tachycardia or bradycardia

- Dysrhythmia or pulse deficits
- Pulsus paradoxus—a decrease in pulse pressure associated with inspiration, an increase in pulse pressure associated with expiration. This is generally associated with pericardial effusion.
- Pale mucous membranes
- Prolonged capillary refill time
- Weak peripheral pulses
- Distended jugular veins or jugular pulses
- Tachypnea, crackles
- Cough
- Decreased arterial blood pressure
- Hypothermia
- Marked muscular weakness
- Dull mentation
- Cool extremities



DIFFERENTIAL DIAGNOSIS

- Hypovolemic shock—Often associated with a history of vomiting, diarrhea, blood loss, or fluid loss. Patients are often tachycardic or bradycardic (cats) but dysrhythmias or pulmonary edema are less common.
- Distributive shock—May present similarly to hypovolemic shock; may present with other clinical signs of infection such as abdominal pain.
- Hypoxic shock—Patients in hypoxic shock have severe respiratory distress, with increased lung sounds, crackles, or cyanosis.



DIAGNOSTICS

- Thoracic radiographs may reveal cardiomegaly, distended pulmonary vasculature, pulmonary edema or pleural effusion. In cases of DCM or pericardial effusion a globoid heart may be appreciated.
- Echocardiography may show a decrease in cardiac contractility, inflow or outflow obstruction, valvular lesions, or pericardial effusion/tamponade.
- Electrocardiography may show dysrhythmias (atrial fibrillation common in cases of DCM), sinus tachycardia, or electrical alternans (alternation of QRS complex size between beats, associated with pericardial effusion).
- Blood lactate—In cases of impaired oxygen delivery to the tissues and disturbances in tissue perfusion, anaerobic metabolism results in the production of lactate. The normal lactate in adult dogs and cats is less than 2.5 mmol/L and levels over 7 mmol/L indicate severe tissue hypoxia. In resuscitation, serial measurements of blood lactate can help measure the effectiveness of therapy.

- Electrolytes—Hyperkalemia may occur in patients with severe renal injury and oligo-anuria. Pericardial effusion can lead to hyponatremia and hyperkalemia. Lasix therapy can result in hypochloremia and hypokalemia.
- Complete blood count may show a stress leukogram.
- Liver enzyme activities are commonly elevated secondary to impaired hepatic perfusion.
- Renal values may be elevated either secondary to pre-renal azotemia (associated with a concentrated urine specific gravity >1.025 in dogs, >1.035 in cats), or primary renal azotemia secondary to renal hypoxia and ischemic injury
- Central venous pressure can be an aid in assessing volume status objectively and monitoring for risk of congestive heart failure, with a goal of 5 to 10 cm H₂O in a dog and 2 to 5 cm H₂O in a cat.
- A urinary catheter may be placed to monitor urine output if there is concern for oliguria or anuria. The goal is at least 0.5 to 1 ml/kg per hour.

Pathological Findings

- Myocardial fibrosis and scarring may be present, as well as ischemia secondary to impaired myocardial blood flow and increased work of the myocardial cells to try and compensate for the decrease in cardiac output.
- Pulmonary edema and interstitial pneumonia may be seen in cases secondary to the congestive heart failure, hypoxia, and ischemia in the pulmonary cells.
- Hyperemia and ulceration of the intestinal mucosa may occur secondary to impaired splanchnic perfusion and inflammatory mediators.
- Acute tubular necrosis occurs secondary to decreased renal blood flow and impaired oxygen delivery to the tubular cells.



THERAPEUTICS

- The objective of treatment is to improve cardiac output and oxygen delivery to the tissues.
- Pericardiocentesis is imperative for treatment of any patient with pericardial tamponade.
- Positive inotropic support should be provided if contractility is poor and associated with hypotension.
- Antiarrhythmia medications to control rate if arrhythmia is associated with severe pulse deficits, inadequate time for ventricular filling, or hypotension.
- Congestive heart failure should be treated to improve oxygenation and stabilize the patient.
- Oxygen supplementation—either via mask, oxygen cage, or oxygen hood.

Drug(s) of Choice

- Positive inotropic support may be provided with pimobendan (dogs only), a calcium sensitizing agent, dose 0.1 to 0.3 mg/kg orally every 12 hours, or dobutamine at 2 to 20 μ g/kg per minute in dogs and 1 to 5 μ g/kg per minute in cats.

- Treatment of the congestive heart failure with a diuretic, Lasix 2 to 4 mg/kg IV or IM every 30 minutes to get out of failure, then 2 mg/kg every 6 to 12 hours
- In severe cases, nitroprusside can be used in dogs and cats as a vasodilator to treat congestive heart failure and improve cardiac output by reducing afterload at a dose of 2 to 10 µg/kg per minute. This is a potent vasodilator so blood pressure should be monitored closely to watch for hypotension. If hypotension occurs, the nitroprusside should be stopped immediately. In addition, sustained nitroprusside therapy can result in cyanide toxicity, particularly in patients with renal impairment.
- Supraventricular arrhythmias may be treated with diltiazem, dose in dogs 0.25 mg/kg intravenous bolus over 2 minutes, repeat 0.25 mg/kg IV every 15 minutes until conversion occurs or up to a total dose of 0.75 mg/kg; in cats 0.5 to 1 mg/kg (up to 1.5) mg/kg PO or per rectum every 8 hours.
- Oxygen supplementation should be provided; this can be done via oxygen mask, oxygen cage, or nasal cannula. In cases of severe respiratory distress that is unresponsive to diuretic therapy or in which respiratory arrest is imminent, sedation, intubation, and mechanical ventilation are warranted.

Precautions/Interactions

- In patients in cardiogenic shock, blood pressure must be monitored closely and continuously when the patient is on nitroprusside to avoid hypotension.
- Treatment of the tachycardia may result in hypotension if the tachycardia is a compensatory response to poor cardiac output. Treatment with a positive inotrope should be instituted to provide myocardial support.
- Nonsteroidal anti-inflammatory medications should be avoided in patients with compromised perfusion to decrease risk of renal and gastrointestinal complications.

Diet

- Once the patient has stabilized, enteral or parenteral nutrition should be instituted to address the nutritional needs of the patient.



COMMENTS

Client Education

- Owners should be warned of the risk of sudden death in any patient that presents in cardiogenic shock.
- In patients that experience a severe hypotensive state and are discharged with residual neurologic impairments, the owner needs to be educated that full neurologic recovery may take weeks to months.

Patient Monitoring

- Serial lactate measurements every 8 to 12 hours once normalized

- Central venous pressure—either continuous or every 8 to 12 hours to monitor
- Blood pressure monitoring—every 8 to 12 hours to monitor for hypotension
- ECG—every 8 to 12 hours or continuous to monitor for dysrhythmias

Possible Complications

- Renal dysfunction
- Cardiac dysrhythmias
- Gastroenteritis, hemorrhagic gastroenteritis
- Bacterial translocation, sepsis
- Residual neurologic impairment
- Cardiac arrest

Expected Course and Prognosis

- Variable pending the underlying cause and severity of clinical condition

Abbreviations

- DCM: dilated cardiomyopathy
- ECG: electrocardiogram
- IM: intramuscularly
- IV: intravenously
- PO: by mouth

See Also

- Shock—Hypovolemic
- Shock—Distributive
- Dilated Cardiomyopathy (DCM)
- Hypertrophic Cardiomyopathy
- Pericardial Effusion (PE)

Suggested Reading

- Ayers, SM, Grenvik, A, Holbrook, PR, and Schoemaker, SC. *Textbook of Critical Care*, 3rd ed., pp. 1037–1045. Philadelphia: W.B. Saunders, 1995.
- DiBartola, SP. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed., pp. 544–545. St. Louis: Saunders Elsevier, 2006.
- Silverstein, DC, and Hopper, K. *Small Animal Critical Care Medicine*. St. Louis: Saunders Elsevier, 2009.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Nishi Dhupa

Shock—Distributive



DEFINITION/OVERVIEW

- Shock occurs when the patient is unable to provide effective circulating volume and oxygen delivery to the tissues. There are numerous classification categories for shock. In any case, the underlying problem is that the oxygen delivery is not sufficient to meet the oxygen needs of the tissues resulted in a cellular oxygen and energy debt. It is important to note that although there may be one predominant category that a specific patient falls into, one must consider all of the aspects of each of the categories when formulating a treatment plan. For example, in patients with septic shock, they often have significant protein and fluid losses resulting in hypovolemic shock, as well as myocardial dysfunction that may present as cardiogenic shock. So although the different categories of shock will be presented, care must be taken to approach each patient with an open mind and the realization that in any patient the categories may overlap considerably.
- Distributive shock describes a condition of relative hypovolemia in which there is massive vasodilation resulting in pooling of the circulating blood volume and impaired tissue perfusion and oxygen delivery.



ETIOLOGY/PATHOPHYSIOLOGY

- Distributive shock has numerous etiologies. The most common cause is septic shock, but can also occur in anaphylactic and neurogenic shock, as well.
- Sepsis is defined as a SIRS secondary to an infectious process. Septic shock is a progression of this inflammatory response resulting in cardiovascular dysfunction and compromise.
- Sepsis can be caused by gram positive, gram negative, aerobic or anaerobic infections, but gram negative infections are a common cause of septic shock. In gram negative infections, endotoxin, or LPS, is a component of the outer bacterial cell membrane and plays a significant role in the stimulation of the inflammatory cascade.
- Endotoxin also stimulates the release of inflammatory cytokines such as TNF- α , IL-1, and IL-6. These cytokines have numerous systemic effects including vasodilation, myocardial depression, increased gut permeability, and pulmonary inflammation.
- Common causes of septic shock include septic peritonitis resulting from rupture of gastrointestinal viscera and leakage of intestinal contents or rupture of the urinary

or gall bladder with a concomitant urinary tract or biliary infection, pyometra, pneumonia, prostatic infection/abscess, pyelonephritis, meningitis, bite wounds, bacterial endocarditis, or bacterial translocation from severe gastrointestinal disease.

- Anaphylaxis is a severe allergic reaction to an allergen, antigen, drug or foreign protein that leads to release of histamine, extensive vasodilation and increased capillary permeability.
- Neurogenic shock occurs when severe trauma to the spinal cord results in the loss of autonomic and motor reflexes below the injury level. The lack of stimulation by the sympathetic nervous system leads to systemic vasodilation and hypotension. This form of distributive shock is very rare.

Systems Affected

- Cardiovascular—Sepsis leads to the release of inflammatory cytokines that can cause direct myocardial dysfunction. This sepsis induced myocardial depression is characterized by impaired contractility leading to decreased cardiac output and potential congestive heart failure. In humans, this myocardial depression is completely reversible if the underlying sepsis resolves. These cytokines also have direct effects on the vasculature leading to vasodilation and capillary leak. In addition the lactic acidosis that develops secondary to poor perfusion and impaired oxygen delivery to the tissues can impair the vascular response to catecholamines.
- Pulmonary—Inflammatory cytokines, such as $\text{TNF-}\alpha$, have been shown to lead to capillary leak and acute lung injury/ ARDS. Additionally, the myocardial dysfunction secondary to sepsis can result in pulmonary edema secondary to increased pressure in the pulmonary vascular bed.
- Renal—When the mean arterial blood pressure decreases below 60 mm Hg, the kidneys are no longer able to autoregulate and hypotension directly impairs renal blood flow and oxygen delivery. The kidneys are extremely sensitive to impaired perfusion, and this may result in renal ischemia and acute tubular necrosis, renal failure, and oliguria. The significant systemic inflammatory response can also lead to differential vasodilation and vasoconstriction in the vascular beds further diminishing oxygen delivery to the kidneys.
- Gastrointestinal—The splanchnic circulation is also compromised in cases of impaired perfusion, systemic inflammation, impaired vascular tone, and elevations in circulating cytokines. This can result in significant damage to the mucosa, ulceration, the loss of the intestinal blood barrier, and subsequent bacterial translocation, intestinal necrosis, and hemorrhage. The combination of decreased splanchnic perfusion, pooling of blood in vascular beds, and significant systemic inflammation also affects the pancreas and can lead to pancreatitis and further release of inflammatory mediators into both the abdominal cavity as well as the peripheral circulation.
- Hepatic—The liver is particularly sensitive to the impaired perfusion and circulating inflammatory mediators that occur in distributive shock. In addition, the inflammatory cytokines also have a direct effect on the hepatocytes and can lead to sepsis-induced cholestasis, hepatocellular dysfunction, and death. This may lead to impaired

hepatic function including a decrease in gluconeogenesis and subsequent hypoglycemia, decrease in the production of clotting factors, decreased protein synthesis, and hyperbilirubinemia.

- **Nervous**—Central nervous system dysfunction is a significant complication in patients with impaired oxygen delivery and disturbances of the oxygen delivery to consumption ratio. In addition, the coagulation abnormalities associated with sepsis and severe systemic inflammation can lead to vascular events (i.e., thrombosis or hemorrhage) affecting the central nervous system. This can result in cerebral ischemia and associated manifestations such as stupor, blindness, and decreased spinal reflexes. The permanence of these neurologic abnormalities is again related to the severity and duration of the shock event.
- **Musculoskeletal**—Musculoskeletal weakness is a common complication in patients with decreased perfusion and oxygen available to the myocytes. This musculoskeletal weakness may be profound, and patients should not be stressed until their perfusion is improved.
- **Endocrine/metabolic**—Relative adrenal insufficiency is a well documented complication of sepsis and septic shock. Although the cause of adrenal insufficiency remains unknown, the most likely culprit is a cytokine-induced decrease in the synthesis or release of corticotropin-releasing hormone, ACTH, and cortisol. This has been associated with an increased vasopressor requirement, prolonged hospitalization, and increased mortality. Diagnosis is a decreased responsiveness to ACTH stimulation, although a definitive level at which relative adrenal insufficiency is defined has not been identified.



SIGNALMENT/HISTORY

- There is no age, breed, or sex predilection for distributive shock; it can occur at any age.

Risk Factors/Causes

- Pre-existing immunosuppression, either due to infectious disease (such as feline leukemia virus, feline immunodeficiency virus, or parvovirus), concurrent clinical conditions such as hyperadrenocorticism, diabetes mellitus, or medications such as long-term steroid use or chemotherapy.

Historical Findings

- Variable pending the underlying cause of the distributive shock
- Vomiting, painful, or distended abdomen
- Previous surgery
- Urinary tract signs in cases of urosepsis
- Concurrent conditions associated with immunosuppression such as feline leukemia, feline immunodeficiency virus, hyperadrenocorticism, or diabetes mellitus

- Long-term steroid use or chemotherapy
- Current or previous history of an allergic reaction (i.e., swelling, urticaria, erythema) associated with an antigenic stimulus (i.e., vaccination, insect bite, medication)



CLINICAL FEATURES

Early or Hyperdynamic Shock

- Tachycardia
- Strong peripheral pulses
- Rapid capillary refill time
- Bright red mucous membranes
- Normal to increased arterial blood pressure
- Normal mentation
- Normal muscular activity and ability
- Tachypnea
- Normal to increased rectal temperature
- This stage is rarely identified in cats.

Late or Decompensatory Shock

- Tachycardia or bradycardia (particularly in cats)
- Pale mucous membranes
- Prolonged capillary refill time
- Weak peripheral pulses
- Tachypnea
- Decreased arterial blood pressure
- Hypothermia (particularly in cats)
- Abdominal pain (cats)
- Marked muscular weakness
- Dull mentation
- Cool extremities
- Evidence of coagulopathy: petechia, ecchymosis, hyphema, or epistaxis



DIFFERENTIAL DIAGNOSIS

- Cardiogenic shock may be associated with a pre-existing cardiac condition, pulmonary edema, muffled heart sounds, or arrhythmias.
- Hypovolemic shock often presents very similarly to distributive shock and initial therapy is similar while investigating the underlying cause.
- Hypoxic shock—patients in hypoxic shock are often severely dyspnic, with increased lung sounds, crackles, or cyanosis.



DIAGNOSTICS

- **Blood lactate**—In cases of impaired oxygen delivery to the tissues and disturbances in tissue perfusion, anaerobic metabolism results in the production of lactate. The normal lactate in adult dogs and cats is less than 2.5 mmol/L and levels over 7 mmol/L indicate severe tissue hypoxia. In resuscitation, serial measurements of blood lactate can help measure the effectiveness of therapy. Monitoring the lactate every 1 to 2 hours as resuscitation is performed can help guide the clinician in the resuscitation efforts and monitoring the lactate every 6 to 8 hours once it has normalized may alert the clinician to new problems if there is an acute increase in the lactate levels. It is important to note that in patients with severely compromised perfusion, the lactate may initially rise after starting fluid therapy and the improved perfusion flushes lactate out of the poorly perfused periphery. This is a transient increase, and as resuscitation continues and blood supply to the tissues increases, the levels should decrease to normal.
- **Packed cell volume and total solids**—In cases of severe systemic inflammation, vasodilation and increased vascular permeability, hypoproteinemia is common. In addition, underlying disease such as peritonitis, gastritis, and hepatic insufficiency exacerbate the decrease in serum protein levels. The hypoproteinemia may be present initially or may develop secondary to ongoing protein loss, decreased production by the liver, decreased intake through the gastrointestinal tract, and dilution from fluid administration. In addition, blood loss through the gastrointestinal tract or other ongoing losses can be exacerbated by blood sampling (particularly in cats) and decreased erythropoietin due to critical illness. Serial monitoring is important to monitor protein levels and identify when additional therapies such as colloid therapy or transfusions are indicated.
- **Electrolytes**—Hyperkalemia may occur in patients with severe renal injury and oligoanuria, hyponatremia, and hyperchloremia may be seen in cases with severe dehydration and water loss.
- **Complete blood count** may show evidence of anemia, a neutrophilia with a left shift associated with infection, leukopenia in severe sepsis, and thrombocytopenia.
- **Liver values** are commonly elevated secondary to impaired hepatic perfusion.
- **Renal values** may be elevated either secondary to prerenal azotemia (associated with a concentrated urine specific gravity >1.025 in dogs, >1.035 in cats), or primary renal azotemia secondary to renal hypoxia and ischemic injury.
- **Central venous pressure** can be an aid in assessing volume status objectively, with a goal of 5 to 10 cm H₂O in a dog and 2 to 5 cm H₂O in a cat.
- **Coagulation times (PT and PTT)** to investigate for any coagulopathies
- **A urinary catheter** may be placed to monitor urine output if there is concern for oliguria or anuria. The goal is at least 0.5 to 1 ml/kg per hour.
- **Thoracic radiographs** may show pulmonary infiltrate associated with acute lung injury, pneumonia, or other parenchymal disease.
- **Abdominal radiographs** may show evidence of free air in the abdomen if there is a rupture of the gastrointestinal tract associated with septic peritonitis.

- ECG may document impaired myocardial contractility secondary to the sepsis associated myocardial dysfunction.
- ECG to evaluate for any cardiac arrhythmias secondary to myocardial ischemia or electrolyte abnormalities

Pathological Findings

- Hyperemia and ulceration of the intestinal mucosa may occur secondary to impaired splanchnic perfusion and inflammatory mediators.
- Acute tubular necrosis occurs secondary to decreased renal blood flow and loss of autoregulation leading to impaired oxygen delivery to the tubular cells.
- Interstitial pneumonia may be seen in cases secondary to the hypoxia and ischemia in the pulmonary cells with subsequent release of inflammatory mediators.
- Myocardial ischemia secondary to impaired myocardial blood flow and increased work of the myocardial cells to try to compensate for the decrease in cardiac output.



THERAPEUTICS

- The objective of treatment is to provide intravascular fluid volume to maintain cardiac preload and thereby blood flow and oxygen delivery to the tissues.
- Identification and treatment of the underlying source of infection are essential in the treatment of septic shock. This may include surgical drainage or resection of infected tissues or aggressive antibiotic therapy in cases of systemic infections such as pneumonia or pyelonephritis.
- Crystalloid therapy with a balanced isotonic solution at an initial rate of up to 90 ml/kg in dogs and 60 ml/kg in cats
- It should be noted that intravenous crystalloids should be used judiciously in cats because the lung is the shock organ in the cat and fluid overload and pulmonary edema can rapidly occur, particularly with concurrent hypotension and hypothermia. An initial bolus of 15 to 20 ml/kg every 15 to 20 minutes up to 60 ml/kg is often effective at providing fluid resuscitation while avoiding fluid overload and pulmonary edema.
- In patients that are hypoproteinemic or remain volume deplete despite crystalloid therapy, colloids such as hetastarch or dextran may be used at a rate of 5 to 10 ml/kg as a bolus in dogs and 3 to 5 ml/kg as a bolus in cats. The total colloid administered should be less than 20 ml/kg per day to avoid secondary coagulopathies.
- Hypertonic saline is another hyperoncotic solution and may be administered at a rate of 5 to 10 ml/kg. The effects of this fluid is rapid, but they do not last very long and care should be taken in hyponatremia patients.
- Hemoglobin based oxygen carriers provide an increased oxygen-carrying ability as well as exert a colloid effect. These substances, such as Oxyglobin, may be useful in improving systemic tissue perfusion and some investigators have theorized they may also improve perfusion to the microvasculature. It should be noted, however, that

the colloidal effect of these substances is profound, and again care should be used when using this fluid choice in our patients, particularly cats, to avoid fluid overload.

- Oxygen supplementation—either via mask, oxygen cage, or oxygen hood.

Drug(s) of Choice

- In cases that remain hypotensive despite fluid resuscitation, vasopressor therapy with dopamine 5 to 20 $\mu\text{g}/\text{kg}$ per minute, norepinephrine 0.05 to 2 $\mu\text{g}/\text{kg}$ per minute, or epinephrine 0.005 to 1 $\mu\text{g}/\text{kg}$ per minute may be utilized. Alternatively, positive inotropy may also be provided using dobutamine 2 to 20 $\mu\text{g}/\text{kg}$ per minute in dogs and 1 to 5 $\mu\text{g}/\text{kg}$ per minute in cats.

Precautions/Interactions

- Nonsteroidal anti-inflammatory medications should be avoided in patients with compromised perfusion to decrease risk of renal and gastrointestinal complications.

Diet

- Once the patient has stabilized, enteral or parenteral nutrition should be instituted to address the hypermetabolic state the patient is in.

Surgical Considerations

- Aggressive drainage or debridement of any devitalized tissue is warranted to remove the source of infection.



COMMENTS

Client Education

- In patients that experience a severe hypotensive state and are discharged with residual neurologic impairments, the owner needs to be educated that full neurologic recovery may take weeks to months.

Patient Monitoring

- Serial lactate measurements every 8 to 12 hours once normalized
- Central venous pressure—either continuous or every 8 to 12 hours to monitor
- Blood pressure monitoring—every 8 to 12 hours to monitor for hypotension
- ECG—every 8 to 12 hours or continuous to monitor for arrhythmias
- Blood glucose—every 12 to 24 hours

Possible Complications

- Renal dysfunction

- Cardiac arrhythmias
- Gastroenteritis, hemorrhagic gastroenteritis
- Bacterial translocation, sepsis
- Residual neurologic impairment
- Cardiac arrest

Expected Course and Prognosis

- Variable pending the underlying cause and severity of clinical condition

Abbreviations

- ACTH: adrenocorticotrophic hormone
- ARDS: adult respiratory distress syndrome
- ECG: electrocardiogram
- IL-1: interleukin-1
- IL-6: interleukin-6
- LPS: lipopolysaccharide
- PT: prothrombin time
- PTT: partial thromboplastin time
- SIRS: systemic inflammatory response syndrome
- TNF- α : tumor necrosis factor- α

See Also

- Shock—Hypovolemic
- Shock—Cardiogenic
- Peritonitis
- Pneumonia
- Parvovirus

Suggested Reading

- Ayers, SM, Grenvik, A, Holbrook, PR, and Schoemaker, SC. *Textbook of Critical Care*, 3rd ed. Philadelphia: W.B. Saunders, 1995.
- DiBartola, SP. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed. St. Louis: Saunders Elsevier, 2006.
- Rose, BD, and Post, TW. *Clinical Physiology of Acid-Base and Electrolyte Disorders*, 5th ed. New York: McGraw-Hill, 2001.
- Silverstein, DC, and Hopper, K. *Small Animal Critical Care Medicine*. St. Louis: Saunders Elsevier, 2009.

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Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Nishi Dhupa

Shock—Hypovolemic



DEFINITION/OVERVIEW

- Shock is defined as any condition that results in inadequate effective circulating volume and oxygen delivery to the tissues. In any classification scheme, the underlying problem is that the oxygen delivery is not sufficient to meet the oxygen needs of the tissues. This leads to a cellular oxygen and energy debt. It is important to note that although there may be one predominant category that a specific patient falls into, one must consider all of the aspects of each of the categories when formulating a treatment plan. For example, a patient with severe GI disease and hemorrhagic diarrhea may initially present in hypovolemic shock, but as the clinical disease progresses the GI blood barrier may become compromised leading to bacterial translocation, systemic septicemia, and septic shock. This can then go on to affect the heart and lead to impaired myocardial contractility, thus exhibiting signs of cardiogenic shock. So although the different categories of shock will be presented, care must be taken to approach each patient with an open mind and the realization that the categories may overlap considerably.



ETIOLOGY/PATHOPHYSIOLOGY

- Hypovolemic shock is a common cause of shock in our veterinary patients.
- Occurs when loss of intravascular fluid leads to decreased venous return to the heart and subsequent decreased in cardiac output. This decrease in effective circulating volume can occur secondary to blood loss (either via external or internal hemorrhage), water loss through the GI tract or the kidneys, water loss through the skin, or third spacing of fluids.
- Decreased cardiac output stimulates the sympathetic nervous system and leads to tachycardia and peripheral vasoconstriction.
- Decreased renal perfusion stimulates the renin-angiotensin-aldosterone system and causes sodium and water retention and stimulates the sympathetic nervous system.
- Decreased perfusion is sensed by the hypothalamus and leads to ACTH-mediated release of cortisol, aldosterone, and catecholamines.
- The goal of these compensatory mechanisms is to maintain cardiac output in the early stages of shock (compensatory phase), but these all require metabolic energy and if the oxygen delivery to the tissues remains less than the demands of the tissue,

the cellular hypoxia and oxygen debt will rapidly progress into organ dysfunction and death. When fluid loss is large enough to overwhelm compensatory mechanisms, it leads to an imbalance between oxygen supply and demand in the tissues. If the oxygen delivery to the tissues remains less than the tissue oxygen demands, cellular hypoxia and oxygen debt will rapidly progress into organ dysfunction and death if not rapidly correct through treatment.

- Common causes of blood loss include rupture of an internal viscus (i.e., splenic or hepatic mass), GI hemorrhage and fluid loss (i.e., parvovirus, NSAID- or steroid-induced gastric ulceration, or other primary intestinal disease), trauma and blood loss from a fracture, laceration or internal injury, or hemorrhage secondary to coagulopathy (i.e., rodenticide, inherited factor deficiencies).
- Hypovolemia secondary to fluid loss may include severe GI loss through protracted vomiting or diarrhea, renal water loss secondary to primary renal disease and loss of concentrating ability or diabetes insipidus, water loss through severe burns and cutaneous losses, or third spacing of fluids into the peritoneal cavity.

Systems Affected

- Cardiovascular
 - Decreased cardiac pre-load and cardiac output.
 - Catecholamine induced peripheral vasoconstriction, tachycardia and an increase in myocardial oxygen consumption.
 - Decreased coronary and myocardial perfusion.
 - Myocardial cell ischemia and dysrhythmias.
 - Persistent myocardial cell hypoxia leads to impaired cardiac contractility and further impairs the cardiac output and tissue perfusion.
 - Impaired perfusion leads to a lactic acidosis which impairs the vascular responsiveness to catecholamines (both endogenous and exogenous).
 - Cats may exhibit bradycardia or tachycardia.
- Pulmonary
 - Increased minute ventilation and respiratory rate during early stages of hypovolemic shock causes increased pulmonary oxygen consumption.
 - Impaired pulmonary parenchymal perfusion leads to cellular dysfunction, cell swelling, and release of inflammatory mediators.
 - Inflammatory mediators can then result in acute lung injury and eventually acute respiratory distress syndrome as high protein fluid leaks from the parenchymal cells into the alveolar space. This can further impair oxygenation and oxygen delivery to the tissues.
 - The lungs are commonly described as the shock organ in the cat.
- Renal
 - In the early stages of shock the autoregulatory ability of the kidneys is able to maintain blood flow via vasoconstriction of the afferent arteriole and sodium and water retention.

- When the mean arterial blood pressure decreases below 60 mmHg, the kidneys are no longer able to autoregulate and hypotension directly impairs the blood flow and oxygen delivery.
- The kidneys are extremely sensitive to impaired perfusion and decreased GFR; this may result in renal ischemia and acute tubular necrosis, and oliguria.
- **Gastrointestinal**
 - The splanchnic circulation is significantly compromised in cases of impaired perfusion. The GI tract is considered to be the shock organ in dogs, so impaired GI function is common with hypovolemic shock.
 - The compensatory mechanisms and increase in catecholamines and vasoconstriction can significantly impair blood flow to the intestines. This can result in ulceration, the loss of the intestinal blood barrier and subsequent bacterial translocation, intestinal necrosis, mucosal sloughing, and hemorrhage.
 - Decreased splanchnic perfusion can also affect the pancreas, leading to pancreatitis and release of inflammatory mediators into both the abdominal cavity as well as into peripheral circulation.
 - Ileus, vomiting, and diarrhea may be observed as a consequence of hypovolemia and hypotension.
- **Hepatic**
 - The decreased oxygen delivery can cause ischemia and cellular death in the hepatocytes. This can further lead to impaired hepatic function including a decrease in gluconeogenesis and subsequent hypoglycemia, decrease in the production of clotting factors, decreased protein synthesis, and intrahepatic cholestasis.
 - The extent, severity and duration of the dysfunction are variable and related to both the severity as well as the duration of the impaired perfusion and decreased oxygen delivery. In severe cases, coagulopathies and hepatic failure can result.
- **Nervous**
 - In patients with impaired oxygen delivery and disturbances of the oxygen delivery to consumption ratio, neurologic impairment may occur.
 - Delirium and cognitive defects are common in humans, but less appreciated in our veterinary patients.
 - In cases of severe shock in which the blood flow to the brain is significantly impaired, cerebral ischemia may develop and clinical manifestations such as stupor, blindness, and decreased spinal reflexes may be noted.
 - The permanence of these neurologic abnormalities is again related to the severity and duration of the shock event.
- **Musculoskeletal**
 - Musculoskeletal weakness is common in patients in shock. The decreased perfusion results in lactate production and decreased oxygen available to the myocytes.
 - This musculoskeletal weakness may be profound, and patients should not be stressed until their perfusion is improved.

- Endocrine/metabolic
 - Marked decreases in blood flow to the adrenal glands can result in ischemia and infarction to these organs.
 - Adrenal ischemia can result in decreased function and decreased glucocorticoid or mineralocorticoid production. Relative adrenal insufficiency is common in shock states in humans and can exacerbate poor responsiveness to fluid therapy.
 - In addition, severe systemic stress that occurs secondary to the hypotensive crisis can lead to both insulin resistance as well as decreased insulin production secondary to severe ischemia to the pancreas, resulting in hyperglycemia.
- Skin/exocrine
 - In cases of severe burn injury or significant cutaneous wounds, dramatic water loss can occur and this may lead to a hypotensive crisis. In these cases, care should be taken to address the wounds as soon as possible to minimize additional fluid loss.



SIGNALMENT/HISTORY

- There is no age, breed, or sex predication for hypovolemic shock, and it can occur at any age.

Risk Factors/Causes

- There are no specific risk factors associated with the development of hypovolemic shock.
- Predisposing coagulopathies (either inherited factor deficiencies, contact with anti-coagulant rodenticides or thrombocytopenia)
- Gastric ulceration secondary to steroidal or nonsteroidal anti-inflammatory therapy
- Exposure to parvovirus and inadequate vaccination status
- In cases of severe GI loss, owner will describe profound or protracted vomiting, diarrhea, or hemorrhagic diarrhea.
- In cases of traumatic blood loss from blunt or penetrating injuries, clients may describe the amount or volume of blood loss or the duration of bleeding. In addition, owners may note a progressive decrease in the mentation and activity as the condition progresses.
- Surgical blood loss with uncontrolled hemostasis
- Third spacing fluid loss into body cavities such as the pleural, peritoneal, or retro-peritoneal space. Severe subcutaneous edema.

Historical Findings

- In cases of severe GI loss, owner will describe profound or protracted vomiting, diarrhea, or hemorrhagic diarrhea.
- In cases of traumatic blood loss, owners may describe the amount or volume of blood loss or the duration of bleeding. In addition, owners may note a progressive decrease in the mentation and activity as the condition progresses.



CLINICAL FEATURES

Early or Compensated Shock

- Tachycardia
- Normal to strong peripheral pulses
- Rapid capillary refill time
- Normal to increased arterial blood pressure
- Normal mentation
- Normal muscular activity and ability
- Tachypnea
- Normal to increased rectal temperature
- Early signs may be subtle.

Late or Decompensatory Shock

- Tachycardia or bradycardia (particularly in cats)
- Pale mucous membranes
- Prolonged capillary refill time
- Weak peripheral pulses
- Decreased arterial blood pressure
- Hypothermia (particularly in cats)
- Abdominal pain (cats)
- Marked muscular weakness
- Dull mentation
- Cool extremities



DIFFERENTIAL DIAGNOSIS

- Cardiogenic shock may be associated with a pre-existing cardiac condition, pulmonary edema, muffled heart sounds, or arrhythmias.
- Distributive shock often presents very similarly to hypovolemic shock and initial therapy is similar while investigating the underlying cause.
- Hypoxic shock—patients in hypoxic shock are often severely dyspnic with increased lung sounds, crackles, or cyanosis.



DIAGNOSTICS

- Blood lactate
 - Lactate production secondary to impaired tissue perfusion and oxygen delivery.
 - Normal lactate in adult dogs and cats is less than 2.5 mmol/L.
 - Lactate >7 mmol/L indicates severe tissue hypoxia.

- Serial blood lactate measurements can help measure the effectiveness of fluid resuscitation therapy.
 - Monitor every 1 to 2 hours to guide resuscitation efforts.
 - Monitor every 6 to 8 hours once lactate has normalized.
 - May alert the clinician to new problems if there is an acute increase in the lactate levels.
 - Note: in patients with severely compromised perfusion, the lactate may initially rise after starting fluid therapy and the improved perfusion flushes lactate out of the poorly perfused periphery. This is a transient increase, and as resuscitation continues and blood supply to the tissues increases, the levels should decrease to normal.
- PCV and total solids
 - In cases of hemorrhagic shock, the blood loss may not initially be apparent due to splenic contraction in dogs (splenic contraction has a much less marked effect in cats) or ongoing blood loss.
 - Once the patient has received intravenous fluids to help improve perfusion, the PCV may decrease significantly.
 - In cases of ongoing blood loss, serial monitoring is important to determine when and if the patient needs blood component therapy.
 - Protein loss, either via the GI tract, hemorrhage, or cutaneous loss, may also contribute significantly to the hypovolemia. Serial monitoring of this will also help guide the clinician as to when colloids are indicated. Measurement of the packed cell volume and total solids every 6 to 8 hours is indicated to identify and guide treatment in these cases.
- Electrolytes—Hyperkalemia may occur in patients with severe renal injury and oligoanuria, hypernatremia, and hyperchloremia may be seen in cases with severe dehydration and water loss.
- Complete blood count may show evidence of anemia and a stress leukogram, and provide a platelet count
- Liver values are commonly elevated secondary to impaired hepatic perfusion.
- Renal values may be elevated either secondary to prerenal azotemia (associated with a concentrated urine specific gravity >1.025 in dogs, >1.035 in cats), or primary renal azotemia secondary to renal hypoxia and ischemic injury.
- Central venous pressure can be an aid in assessing volume status objectively, with a goal of 5 to 10 cm H₂O in a dog and 2 to 5 cm H₂O in a cat.
- Coagulation times (PT and PTT) to investigate for any coagulopathies
- A urinary catheter may be placed to monitor urine output if there is concern for oliguria or anuria. The goal is at least 0.5 to 1 ml/kg per hour.
- ECG to evaluate for any cardiac arrhythmias secondary to myocardial ischemia or electrolyte abnormalities
- Thoracic radiography can allow visualization of subjective cardiac size, and appearance of the caudal vena cava. The cardiac silhouette may be slightly elevated from the sternum on a lateral thoracic radiograph of an animal with hypovolemic shock. Additionally, the caudal vena cava may appear smaller than normal.

Pathological Findings

- Hyperemia and ulceration of the intestinal mucosa may occur secondary to impaired splanchnic perfusion and inflammatory mediators.
- Acute tubular necrosis occurs secondary to decreased renal blood flow and loss of autoregulation leading to impaired oxygen delivery to the tubular cells.
- Interstitial pneumonia may be seen in cases secondary to the hypoxia and ischemia in the pulmonary cells with subsequent release of inflammatory mediators.
- Myocardial ischemia secondary to impaired myocardial blood flow and increased work of the myocardial cells to try to compensate for the decrease in cardiac output.
- Microvascular thrombosis and hemorrhage may be apparent in affected tissues.



THERAPEUTICS

- The objective of treatment is to restore intravascular fluid volume to maintain cardiac preload and thereby improve cardiac output, tissue blood flow, and oxygen delivery. In cases of ongoing blood loss secondary to a bleeding mass or injury, surgical intervention to control the hemorrhage should be done as soon as possible, stabilizing the patient as much as possible prior to anesthesia.
- Crystalloid therapy with a balanced isotonic solution at an initial rate of up to 90 ml/kg in dogs and 60 ml/kg in cats (titrate in incremental doses while monitoring heart rate, blood pressure, and capillary refill time); one method is to administer one-fourth of the calculated volumes listed, then reassess perfusion parameters of heart rate, blood pressure, capillary refill time, pulse quality, and urine output.
- In patients that are hypoproteinemic or remain volume deplete despite crystalloid therapy, colloids such as hetastarch or dextran may be used at a rate of 5 to 10 ml/kg as a bolus in dogs and 3 to 5 ml/kg as a bolus in cats. Ideally, the total colloid administered should be less than 20 ml/kg per day to avoid secondary coagulopathies.
- Hypertonic saline is another hyperoncotic solution and may be administered at a rate of 5 to 10 ml/kg. The effects of this fluid is rapid, but do not last very long and care should be taken in hypernatremia patients.
- Hemoglobin based oxygen carriers provide an increased oxygen carrying ability as well as exert a colloid effect. These substances, such as Oxyglobin, may be useful in improving tissue perfusion systemically and some investigators have theorized they may also improve perfusion to the microvasculature. It should be noted, however, that the colloidal effect of these substances is profound and care should be used to avoid intravascular volume overload.
- Whole blood, plasma, or PRBCs also may be considered in anemia or hypocoagulable patients.
- Oxygen supplementation—either via mask, oxygen cage, or oxygen hood.

Drug(s) of Choice

- In cases that remain hypotensive despite fluid resuscitation, vasopressor therapy with dopamine 5 to 20 mcg/kg per minute, norepinephrine 0.05 to 2 µg/kg per minute, or

epinephrine 0.005 to 1 µg/kg per minute may be utilized. Alternatively, positive inotropy may also be provided using dobutamine 2 to 20 µg/kg per minute in dogs and 1 to 5 µg/kg per minute in cats.

- Broad-spectrum antibiotics may be considered when bacterial translocation can exist. Avoid nephrotoxic drugs such as gentamycin and amikacin until hypovolemia, hypotension, and renal perfusion have been adequately restored. Ampicillin (10–40 mg/kg IV three to four times daily) or Timentin (50 mg/kg three times daily), enrofloxacin (5–10 mg/kg every 24 hours), and metronidazole (7.5–15 mg/kg IV three times daily) provide triple antibiotic coverage for high-risk patients.

Precautions/Interactions

- Nonsteroidal anti-inflammatory medications should be avoided in patients with compromised perfusion to decrease risk of renal and GI complications, due to decreases in vasodilatory prostaglandins.
- Corticosteroids have shown no documented benefits in the treatment of shock and can also increase the risk of GI ulceration and immunosuppression in higher doses.
- Corticosteroids may be indicated at physiologic doses in cases of suspected relative adrenal insufficiency based on refractory hypotension after adequate fluid resuscitation and vasopressor therapy have been attempted first.

Diet

- Once the patient has stabilized, enteral or parenteral nutrition should be instituted to address the hypermetabolic state the patient is in.

Surgical Considerations

- In patients with ongoing hemorrhage, stabilizing them prior to anesthesia is challenging and may require simultaneous administration of fluids, blood products, and rapid anesthetic induction.
- The majority of blunt trauma cases with hemoabdomen or hemothorax do not require surgical intervention because bleeding resolves in most cases with fluid and blood component therapy alone.



COMMENTS

Client Education

- In patients that experience a severe hypotensive state and are discharged with residual neurologic impairments, the owner needs to be educated that full neurologic recovery may take weeks to months.

Patient Monitoring

- Serial lactate measurements every 8 to 12 hours once normalized

- Central venous pressure—either continuous or every 8 to 12 hours to monitor
- Blood pressure monitoring—every 8 to 12 hours to monitor for hypotension
- ECG—every 8 to 12 hours or continuous to monitor for arrhythmias
- Blood glucose—every 12 to 24 hours
- Pulse oximetry to evaluate oxygenation every 2 to 4 hours
- Frequent evaluation of patient's heart rate, respiratory rate, capillary refill time, and mentation

Prevention/Avoidance

- Careful attention to hemostasis intra-operatively and monitoring of PCV and perfusion parameters postoperatively helps to reduce the risk of significant blood loss.
- In patients with large volumes of vomit, diarrhea, or third spacing of fluids, hypovolemia can occur rapidly so recording sensible fluid losses and frequent body weight changes in addition to the urine output helps to match fluid requirements appropriately.

Possible Complications

- Renal dysfunction
- Acid-base abnormalities
- Anemia
- Hypoalbuminemia
- Cardiac arrhythmias
- Gastroenteritis, hemorrhagic gastroenteritis
- Bacterial translocation, sepsis
- Residual neurologic impairment
- ARDS, SIRS, MODS, sepsis
- Cardiac arrest

Expected Course and Prognosis

- Variable pending the underlying cause and severity of clinical condition

Abbreviations

- ACTH: adrenocorticotrophic hormone
- ARDS: acute respiratory distress syndrome
- ECG: electrocardiogram
- GFR: glomerular filtration rate
- GI: gastrointestinal
- IV: intravenously
- MODS: multiple organ dysfunction syndrome
- NSAID: Nonsteroidal anti-inflammatory
- PCV: packed cell volume
- PRBC: Packed red cell transfusion

- PT: prothrombin time
- PTT: partial thromboplastin time
- SIRS: systemic inflammatory response

Suggested Reading

- Ayers, SM, Grenvik, A, Holbrook, PR, Schoemaker, SC. *Textbook of Critical Care*, 3rd ed. Philadelphia: W.B. Saunders, 1995.
- DiBartola, SP. *Fluid, Electrolyte, and Acid-Base Disorders in Small Animal Practice*, 3rd ed. St. Louis: Saunders Elsevier, 2006.
- Muir, W. Trauma: physiology, pathophysiology, and clinical implications. *J Vet Emerg Crit Care* 2006;16(4):253–263.
- Prittie, J. Optimal endpoints of resuscitation and early goal directed therapy. *J Vet Emerg Crit Care* 2006;16(4):29–339.
- Rose, BD, and Post, TW. *Clinical Physiology of Acid-Base and Electrolyte Disorders*, 5th ed. New York: McGraw-Hill, 2001.
- Silverstein, DC, and Hopper, K. *Small Animal Critical Care Medicine*. St. Louis: Saunders Elsevier, 2009.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Nishi Dhupa

Smoke Inhalation



DEFINITION/OVERVIEW

- Inhalation injury from smoke and the noxious products of combustion in fires.



ETIOLOGY/PATHOPHYSIOLOGY

- The three primary mechanisms that lead to injury in smoke inhalation are: thermal damage, asphyxiation, and pulmonary irritation.

Thermal Damage

- Direct burns are usually limited to the nasal and oral pharyngeal mucosa and the upper airways. This is due to the efficient heat exchange capacity of the upper airways. Inflammation and edema of the supraglottic area and larynx occur within the first several hours of injury. Steam and soot (airborne particulate matter $<3\mu\text{m}$ in size) may cause thermal injuries to the lower airways and alveoli.

Asphyxiation

- Tissue hypoxia can occur secondary to several mechanisms that include a decrease in the FiO_2 (hypoxic asphyxia), decreased ability to carry oxygen (functional anemia), decreased tissue perfusion (hypovolemia, shock), and disruption of the cells' ability to utilize oxygen (altered cellular respiration) that leads to anaerobic metabolism.
- Combustion progressively consumes oxygen and significantly decreases the ambient concentration of oxygen from average 21 percent to as low as 15 percent. The decrease in FiO_2 leads to hypoxemia.
 - CO is a common component of smoke produced by the incomplete combustion of any organic material.
 - CO causes tissue hypoxia by decreasing the oxygen-carrying capacity of the blood. Hemoglobin binds CO with an affinity more than 200 times greater than hemoglobin's affinity for oxygen.
 - CO also causes a left shift in the hemoglobin/oxygen saturation curve and prevents release of oxygen to the tissues.
 - CO has been shown to poison the mitochondrial cytochrome oxidase chain, as well as decrease myocardial contractility by binding to myocardial myoglobin.

- Combustion of common household substances such as plastic, polyurethane, wool, silk, nylon, rubber, and paper products can lead to the production of cyanide gas. Cyanide is a chemical asphyxiant that interferes with cellular metabolism by binding to the ferric ion on cytochrome c oxidase, and subsequently halts cellular respiration. As a result, anaerobic metabolism ensues, with corresponding high lactate acidosis.
- Methemoglobinemia occurs in fire due to heat denaturation of hemoglobin, oxides produced in fire, and metHb-forming materials such as nitrites. The pathophysiologic consequences of metHb formation are a decrease in the oxygen-carrying capacity of the blood and a shift of the oxyhemoglobin dissociation curve to the left, similar to that seen with production of HbCO.

Pulmonary Irritation

- Chemical irritants in smoke include sulfur dioxide, hydrogen chloride, ammonia, and acroleins.
- Soot heightens the effect of the aforementioned irritants by binding them and allowing adherence and reaction with respiratory mucosal surfaces.
- Irritants can cause direct mucosal tissue injury, acute reflexive bronchoconstriction, and intense pulmonary inflammation.
- The direct injury to the pulmonary mucosa is a consequence of the size of the particles, particle's water solubility, and their acid-alkaline properties. The inflammatory reaction develops secondary to the initial irritant injury to respiratory mucosal cells. Inhaled soot and toxic gases generate increased airway resistance by promoting inspissated secretions, increased mucosal airway edema, and reflexive bronchospasm. Damaged mucosal cells stimulate copious exudates rich in protein, inflammatory cells, and necrotic debris.
- With progressive smoke exposure, mucosal sloughing ensues and forms casts of the airways. Airway casts block the passage of oxygen to the alveoli.
- The irritants may also cause acute inactivation of surfactant that leads to atelectasis and decreased pulmonary compliance.

Systems Affected

- Respiratory
- Nervous
- Ophthalmic
- Skin
- Cardiovascular



SIGNALMENT/HISTORY

Risk Factors/Causes

- Fires in closed spaces; usually trapped in burning buildings.
- Residential fires are more common in the winter months.

Historical Findings

- History consistent with smoke exposure, altered mentation, coughing and gagging, respiratory difficulty, and lethargy.



CLINICAL FEATURES

- Clinical signs range in severity from nasal congestion, lacrimation, and mild CNS depression to life-threatening respiratory distress and stuporous/comatose behavior.
- Severity of clinical signs depends on the intensity of the heat produced, duration of exposure, and the composition of the smoke.

Dogs and Cats

- Tachypnea, upper airway sounds and associated increased inspiratory effort, expiratory wheezes, loud bronchovesicular sounds and crackles
- Mental depression, ataxia
- Blepharospasm, hyperemic conjunctiva, sclera hemorrhage (Figure 96.1), corneal ulcers, and rubbing at the eyes
- Smoky smell, singed or burnt fur, whiskers or paw pads (Figure 96.2)
- Hyperemic mucous membranes



■ **Figure 96.1** Scleral hemorrhage is a common clinical finding in dogs with smoke inhalation and burn injury.



■ **Figure 96.2** Cat with curled, singed whiskers as a result of being in a house fire.



DIFFERENTIAL DIAGNOSIS

- Animals commonly have soot covering their fur and a smoky smell that is suggestive of smoke exposure.

Dogs and Cats

- Anaphylaxis, ARDS, CHF, pneumonia, pleural space disease, pulmonary thromboembolism

Cats

- Feline bronchial disease
- Upper respiratory infection
- Pulmonary edema



DIAGNOSTICS

- Emergency database: PCV, TS, blood glucose, BUN, lactate, electrolytes, and arterial blood gases should be performed in all critically ill patients with smoke exposure.
- Persistent metabolic acidosis and lactic acidosis may indicate carbon monoxide, methemoglobinemia, or cyanide intoxication and secondary tissue hypoxia. Co-oximetry would be helpful to determine the cause of metabolic acidosis.
- Fluorescein stain cornea and check behind nictitans for corneal burns and debris (Figure 96.3)



■ **Figure 96.3** Careful irrigation of the eyes, including behind the nictitans, followed by fluorescein stain should always be performed to rule out corneal injuries.

- Complete blood cell count: Neutrophilia (inflammatory leukogram) or neutropenia (due to neutrophil sequestration in the lungs: poor prognostic sign)
- Serum chemistry may reveal hypoxic renal or hepatic damage.
- Imaging: Thoracic radiographs should always be performed to establish a baseline and progression of lung. Radiographic abnormalities can lag behind clinical progression and vary from normal to bronchointerstitial to alveolar patterns.
- Bronchoscopy and BAL should be performed if there is suspicion of superimposed bacterial pneumonia (moist cough, fever). BAL procedure will allow visual inspection of the upper airways and bronchi, as well as collection for cytological and culture analysis of pulmonary fluid samples.

Pathological Findings

- The clinical sequence of events can be divided into early, intermediate, and late phases.
- In the initial 24 to 36 hours after smoke exposure tissue hypoxia from immediately or delayed effects of heat, irritant gases, and soot. Upper and lower airway obstruction, systemic toxic effects of CO, cyanide, and methemoglobinemia can lead to immediate or delayed neurologic abnormalities. However, if there was minimal exposure to smoke, the damage may be limited to inflammation of the oronasal and ocular mucosal surfaces without any other major sequela.
- If skin burns are present and the respiratory tract is edematous then the injuries are more likely to be life threatening. Burns or edematous respiratory tissue enhance the toxic effects of smoke inhalation and leads to progressive pulmonary dysfunction.

- Asphyxia, pulmonary edema, and bacterial pneumonia are potential long-term complications.
- Bacterial pneumonia secondary to smoke-induced pulmonary injury is the most common late complication and has a mortality rate that approaches 50 percent.
- Cerebral edema can also develop during the long-term phases due to severe or prolonged hypoxia.



THERAPEUTICS

- Maintenance of airway patency, adequate oxygenation and ventilation, stabilization of hemodynamic parameters, and decontamination measures of the skin and eyes.
- Animals with severe upper airway obstruction should be intubated. Supportive care and careful monitoring should be instituted early on in the management of smoke inhalation patients because they have the potential to deteriorate rapidly.
- Tracheostomy should be considered for animals with complete airway obstruction.

Drug(s) of Choice

- Oxygen therapy should be provided through a tight-fitting mask, oxygen cage or an endotracheal tube in order to improve hemoglobin oxygenation and decrease the half-life of HbCO. Administer high-flow humidified oxygen (up to 100 percent concentration) for approximately 2 to 4 hours or longer in critical patients.
- Severe cases or those that remain hypoxic despite 100 percent oxygen supplementation may require mechanical ventilation with PEEP and repeated bronchoscopic-guided suctioning of airway secretions.
- Titratable intravenous fluid therapy to correct shock and maintain hydration. Consider the use of synthetic colloids (Hetastarch 10–20 ml/kg per day) to prevent pulmonary edema in the face of increased pulmonary vascular permeability.
- Nebulization of saline and coupage to help thin and clear airway secretions.
- Prophylactic antibiotic therapy is not warranted in animals with smoke inhalation. However, animals with fever and WBC changes on the CBC (persistent neutrophilia or neutropenia) should be treated with broad spectrum antimicrobials (i.e., cefazolin or ampicillin each at 22 mg/kg IV every 6 to 8 hours plus enrofloxacin at 10 mg/kg every 24 hours) while awaiting culture and sensitivity results of pulmonary fluid samples.
- Corticosteroids are not recommended as they may predispose to secondary bacterial pneumonia. However, NSAIDs (i.e., carprofen 2.2 mg/kg SQ or PO [dog] every 12 hours; meloxicam 0.1 mg/kg SQ or PO every 24 hours) and analgesics (fentanyl 2–4 µg/kg per hour IV CRI or buprenorphine 15 µg/kg IV, IM, SQ or sublingual every 8 hours) can relieve inflammation and discomfort.
- Fast-acting bronchodilators such as β_2 -agonists (i.e., albuterol inhalers 90 µg per inhalation: 2 puffs every 4 hours, albuterol prefilled vials of 2.5 mg albuterol in 3-ml sterile saline for nebulization: one vial nebulized every 4 hours, or, terbutaline:

0.01 mg/kg [cats] IM, SQ, or IV every 30 minutes up to four doses) may alleviate reflex bronchoconstriction.

Precautions/Interactions

- Diuretics may cause diuresis and hypovolemia without major beneficial effects on pulmonary or airway edema.
- Corticosteroids should only be used as a single anti-inflammatory dose, if at all, because they may predispose the patient to bacterial pneumonia.

Diet

- Nutritional support (enteral or parenteral) to preserve immune status and prevent a catabolic state.

Activity

- Dependent on oxygen tolerance.

Surgical Considerations

- Debride any devitalized or necrotic tissue.
- Increased risk with general anesthesia and severe pulmonary infiltrates.



COMMENTS

- The pulse oximeter can be misleading in the setting of CO exposure or methemoglobinemia because it measures oxygenated and deoxygenated hemoglobin only and not any other form of hemoglobin. It tends to overestimate the level of oxygenation of hemoglobin due to concurrent binding with CO.
- Co-oximeters transmit four wavelengths of light through a blood sample, instead of two wavelengths transmitted by a pulse oximeter, and in addition to HbO₂, and Hb, are capable of detecting methemoglobin and HbCO.
- Arterial blood gas analysis will also be unable to accurately determine the hemoglobin oxygen saturation as it cannot differentiate between HbO₂ and HbCO saturation. However, serial analysis of the A-a gradient will yield invaluable information on potential progressive pulmonary dysfunction due to the inflammatory responses within the lungs and secondary bacterial infection.

Patient Monitoring

- Respiratory rate and effort, auscultation of the neck and thorax, rectal temperatures (every 4 hours), serial measurements of arterial blood gases, electrolytes and PCV/TS, BUN and lactate (every 24 hours) ensure adequate organ perfusion and resolving hypoxia. CBCs should be repeated (every 24 hours) if there is any evidence of

clinical deterioration such as moist cough or fever. Thoracic radiographs should be repeated in 48 hours to rule out pneumonia, acute lung injury, and pulmonary edema.

Prevention/Avoidance

- Owners should be educated regarding residential sprinkler systems and smoke alarms, fire extinguishers, and stickers for doors that inform rescuers of the quantity and type of animals that live in the residency.

Possible Complications

- Acute phases: Development of bacterial pulmonary infections, acute lung injury, ARDS
- Long term: From asymptomatic to possible chronic pulmonary changes (chronic bronchitis secondary to inflammation and scar tissue formation) and CNS dysfunction (ataxia and abnormal behavior or loss of hearing secondary to delayed effects of CO on the CNS)

Expected Course and Prognosis

- Overall, there is a 90 percent survival rate in dogs and cats with smoke exposure without concurrent evidence of severe skin burns. Deteriorating respiratory function, severe burns, and hypoxic organ damage that occurs within 24 hours of hospitalization carry a poor prognosis.
- Dogs and cats that present with signs that stabilize by 24 hours generally carry a favorable prognosis.

Synonyms

- Smoke exposure
- Smoke toxicity

Abbreviations

- A-a gradient: alveolar to arterial oxygen gradient
- ALI: acute lung injury
- ARDS: acute respiratory distress syndrome
- BAL: bronchoalveolar lavage
- BUN: blood urea nitrogen
- CBC: complete blood count
- CHF: congestive heart failure
- CN: cyanide
- CNS: central nervous system
- CO: carbon monoxide
- CRI: constant rate infusion
- FiO₂: fraction of inspired oxygen

- Hb: deoxyhemoglobin
- HbCO: carboxyhemoglobin
- HbO₂: oxyhemoglobin
- IM: intramuscularly
- IV: intravenously
- met-Hb: methemoglobin
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PCV: packed cell volume
- PEEP: positive end-expiratory pressure
- PO: by mouth
- SQ: subcutaneously
- TS: total solids
- WBC: white blood cell

Suggested Reading

- Drobatz, KJ. Smoke inhalation. In: King, LG, ed. *Textbook of Respiratory Disease in Dogs and Cats*, pp. 480–484. Philadelphia: Saunders, 2004.
- Drobatz, KJ, Walker, LM, and Hendricks, JC. Smoke exposure in cats: 22 cases (1986–1997). *J Am Vet Med Assoc* 1999;215(9):1312–1316.
- Drobatz, KJ, Walker, LM, and Hendricks, JC. Smoke exposure in dogs: 27 cases (1988–1997). *J Am Vet Med Assoc* 1999;215(9):1306–1311.
- Fitzgerald, KT, and Flood, AA. Smoke inhalation. *Clin Tech Small Anim Pract* 2006;21(4):205–214.
- Lafferty, KA. Smoke inhalation. Journal [serial on the Internet]. www.emedicine.com. May 2005.
- Mariani, CL. Full recovery following delayed neurologic signs after smoke inhalation in a dog. *J Vet Emerg Crit Care* 2003;13(4):235–239.

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Snake Bite—Coral Snakes



DEFINITION/OVERVIEW

- Coral snakes are members of the family Elapidae (fixed front-fang snakes).
- Two genera of coral snakes are found in the United States. The Sonoran coral snake *Micruroides euryxanthus* is of central and southeastern Arizona and southwest New Mexico. The other genus is represented by three subspecies of *Micrurus fulvius*, including the Texas coral snake (*M.f. tenere*), the Eastern coral snake (*M.f. fulvius*), and the South Florida coral snake (*M.f. barbouri*).
- The Texas coral snake (eastern and south central Texas, north into southern Arkansas and Louisiana).
- The Eastern coral snake (the eastern seaboard from North Carolina south to Florida, west to Alabama and Mississippi, and throughout eastern Louisiana to the Mississippi River).
- The South Florida coral snake (southern Florida to the northern Florida Keys).

Natural History

- Coral snakes are distinctively colored with an alternating body pattern of black, yellow (occasionally white), and red. They can be distinguished from similar appearing nonvenomous snakes by the color bands. In coral snakes the color bands completely encircle the snake, and the yellow band touches the red.
- In North America only, coral snakes have a black snout. This is easier to differentiate than trying to remember the mnemonic “red or yellow, kill a fellow. Red on black, venom lack.” Simply look for the black snout. (Caution: This does not hold true for South America!)
- Coral snakes have round pupils, no facial pits for heat sensing prey, and their heads are not triangular.
- Coral snakes have short, fixed front fangs and a relatively poor venom delivery system. They must “chew” to inject the venom. Human and animal victims often need the biting snake manually removed.
- The Sonoran coral snake genus *Micruroides* is shy, retiring, nocturnal, small, nonaggressive, and burrowing on contact with humans, dogs, cats, or livestock. Venom potency of this snake is relatively low. Bites to companion animals are unlikely. There are no reported fatalities in humans, dogs, or cats due to envenomation by this snake. The majority of bites in humans occur in handlers.

- The medically important coral snakes are the three subspecies of *Micrurus* (Texas coral, Eastern coral, and South Florida coral snake).
- These snakes are diurnal, docile, but aggressive if disturbed.
- These snakes can be very belligerent if disturbed. Biting snakes may stay attached to victims and need to be removed causing what has been described as a “Velcro” sound.



ETIOLOGY/PATHOPHYSIOLOGY

- Coral snake venom actually is primarily neurotoxic involving little local tissue reaction or pain at the bite site.
- Coral snake venom is a complex mixture of polypeptides including cholinesterase and acetylcholine.
- Several neurotoxins may be involved and act as nondepolarizing postsynaptic neuromuscular blocking agents.
- Coral snake venom induces central nervous system depression, muscle paralysis, and vasomotor instability.
- These neurotoxins combine to produce a “curare-like” syndrome; unlike curare this nondepolarizing blocking of acetylcholine receptor sites has a slow onset and a markedly prolonged duration.
- In dogs, the enzymatic fraction can cause hemolysis and a resultant hemolytic anemia with hemoglobinuria. It has been theorized that phospholipase A is responsible by directly damaging the red blood cell membrane.
- In cats, enzymatic effects may induce myoglobin release.
- Hyaluronidase, phosphodiesterase, proteinase, ribonuclease, and desoxyribonuclease are other enzyme components of coral snake venom that can cause tissue destruction. Nevertheless, tissue necrosis and edema in coral snake bites are nowhere near what is seen in crotalid envenomations.
- Venom uptake can be delayed up to 12 hours or more and can take 7 to 14 days to clear the body.

Toxic Dose

- The severity of coral snake bites is related to both the volume of venom injected and the size of the victim.
- Due to the primitive venom delivery system, snakes must chew and a large percentage of coral snake bites are non-envenomating (“dry”).
- The human lethal dose is 4 to 5 mg of venom.
- A large coral snake can deliver four to five lethal doses in a single bite (20 mg of venom).
- Length of snake positively correlates with the snake’s venom yield.
- Although bites by coral snakes are relatively rare (only 1 percent of all venomous snake bites in humans), it is estimated that the human fatality rate due to coral snake envenomation is as high as 10 percent.

- The volume of venom injected is proportional to the motivation of the snake (i.e., offensive, defensive, or agonal bite) along with the duration of the bite and the intensity of the chewing action.



CLINICAL FEATURES

- The appearance of clinical signs may be delayed as much as 10 to 18 hours.
- Regional signs around the bite can be minimal involving only the puncture wounds, local pain, and possible regional parasthesia.
- Clinical signs next progress to altered mental status, generalized weakness, and muscle fasciculations.
- Next the progression of signs involves paralysis of the limbs and respiratory musculature. This sequence of signs is consistent with bulbar dysfunction.
- Patients can display marked salivation, pharyngeal paralysis, spasms of the masticatory muscles, and respiratory failure.
- Aspiration pneumonia secondary to hypersalivation and dysphagia is not uncommon.
- In addition to these general manifestations, clinical signs of coral snake envenomation vary depending on the species bitten.
- In dogs, hypersalivation, vomiting, acute central nervous system depression, decreased spinal reflexes in all limbs with quadriplegia and respiratory paralysis have been described.
- In addition in canine victims, anemia, hemoglobinuria, intravascular hemolysis, and morphologic alterations of red blood cells may be seen.
- Hypotension and ventricular tachycardia can also be seen in dogs bitten by coral snakes.
- Generally, hemolysis occurs within 72 hours of envenomation.
- Some dogs can show diarrhea and blood-tinged urine.
- In cats, clinical signs after coral snake envenomation include: acute, ascending flaccid quadriplegia, reduced nociperception, and central nervous system depression.
- Additional signs seen in cats can include; hypothermia, anisocoria, loss of cutaneous trunci reflex, and loss of spinal reflexes in all four limbs.
- Cats display hypotension, respiratory depression, and decreased reflexes but maintain normal anal tone and micturition.
- Hemolysis and hemoglobinuria in dogs is not reported in cats.
- Clinical signs from bites of the Sonoran coral snake (*Micruroides euryxanthus*) are much less dramatic. Local pain, weakness of the bitten extremity, and mild local paresthesia all resolve in about 24 hours in humans bitten by these snakes.
- The usual cause of death in coral snake bite victims is respiratory collapse.



DIFFERENTIAL DIAGNOSIS

- Differential diagnosis of coral snake envenomation include: tick paralysis, botulism, macadamia nut ingestion (dogs only), bromethalin, ionophore poisoning, organophosphate toxicity, acute polyneuritis, iatrogenic drug administration, polyradiculoneuritis, and myasthenia gravis.



DIAGNOSTICS

- No specific diagnostic tests exist to establish a coral snake bite.
- Diagnosis depends upon eyewitness accounts, onset of clinical signs, time of year, regional probability, and likelihood of companion animal-snake interaction.
- Local lesions are nondiagnostic, small puncture wounds with minimal swelling.
- Laboratory work should include a complete blood count and biochemical profile.
- Hyperfibrinogenemia, moderate leukocytosis, and elevated creatinine kinase have all been reported in animals after coral snake bite envenomation.
- Elevation of creatinine kinase is an indication envenomation has occurred.
- In dogs, anemia, intravascular hemolysis, and hematuria can occur. Dogs bitten may exhibit burring and spherocytosis of red cells. Monitor canine patients for progressive anemia.
- In cats, increased myoglobin and alkaline phosphatase can occur as a result of rhabdomyolysis.
- Because aspiration pneumonia is a common complication of coral snake envenomation due to dysphagia and pharyngeal paralysis, radiographs of the thorax of envenomated animals may be indicated.



THERAPEUTICS

- The best predictor of successful treatment of coral snake envenomation is early, aggressive therapy.
- Interventions to be avoided include: ice, hot packs, incision, and electroshock therapy. Suction is of limited value.
- Compression bandage wraps involving the entire bitten extremity are recommended for many elapid bites. Recommended is no tighter than wrap for a sprained ankle and not removed until antivenin is administered.
- Because the onset of clinical signs may take several hours, coral snake bite victims must be hospitalized and closely monitored. Pretreatment blood work must be obtained, maintenance intravenous fluid therapy initiated, and cardiac and pulse oximetry monitored.
- Coral snake bite victims must be closely examined for aspiration pneumonia, a common sequela.

- The only definitive treatment for coral snake envenomation is coral snake antivenin (*M. fulvius*) made by Wyeth Laboratories (Marietta, Pennsylvania). There is no other approved coral snake antivenin available.
- However, Australian tiger snake (*Notechis scutatus*) and the Mexican coral snake (*Micrurus* species) antivenins have shown protective cross-reactivity and efficacy against North American coral snake (*M. fulvius fulvius*) venom in mouse models.
- Antivenin is most effective if given early.
- Antivenin is indicated if puncture wounds are discovered, the snake bite was witnessed, or an animal displays suspect clinical signs and companion animal-snake interaction is possible in the region.
- Coral snake antivenin is produced by inoculating horses with venom of the Eastern coral snake. Like crotalid antivenin the final coral snake antivenin is rich in equine proteins responsible for allergic reactions.
- Antivenin is diluted (one vial in 100–200 ml) into crystalloid fluids and given slowly over 30 to 60 minutes while monitoring to prevent an allergic reaction.
- The amount of antivenin needed is calculated relative to the amount of venom injected and the body mass of the victim.
- Smaller patients require higher doses of antivenin since the dose of venom per kilogram of body weight of the victim is higher.
- One vial of coral snake antivenin neutralizes 2 mg of coral snake venom.
- Recommended initial dose of antivenin is one to two vials.
- Antivenin should never be injected into the bite. Uptake of antivenin can be delayed up to 12 hours when given intramuscularly.
- The most common reaction to antivenin is an anaphylactoid response. This reaction can be treated by administration of diphenhydramine and stopping the antivenin infusion.
- True anaphylaxis must be treated with epinephrine, corticosteroids, crystalloid fluids, and stopping the antivenin infusion.
- Antibiotic therapy following coral snake envenomations has fallen out of practice. However, the wide range of pathogenic bacteria found in the mouths of snakes would plead for the use of a broad-spectrum antibiotic.
- Corticosteroid administration is not recommended in the treatment of coral snake envenomation.
- Sonoran coral snake bite victims are much less seriously envenomated. At present no antivenin is available for this venom.
- Sonoran coral snake bite victims are treated supportively and symptomatically.

Prevention/Avoidance

- The most effective preventative effort in diminishing numbers of coral snake bite is companion animal avoidance of prime snake habitat in endemic regions.
- Cats should be kept indoors in areas of known coral snake populations.
- Dogs should never be left unsupervised or running loose in areas known to be home to coral snakes.

- In areas of high snake density often classes are given to train dogs to avoid snakes and snake contacts.
- Rodents can be removed from houses, garages, shed, and yards in an attempt to prevent snakes from being attracted to human habitations and biting companion animals.
- Client education to alert owners to the signs and appearance of snake bite envenomation.

Expected Course and Prognosis

- Prognosis is closely dependent upon the length of time between time of bite and initiation of treatment. Also the size of the snake, the size and species of the victim, and the site of the bite must also be evaluated when considering outcome. The prognosis for all cats is guarded unless early, effective treatment is initiated.

Suggested Reading

- Chrisman, CL, Hopkins, AL, Ford, SL, and Meeks, JC. Acute, flaccid quadriplegia in three cats with suspected coral snake envenomation. *J Am Anim Hosp Assoc* 1996;32:343–349.
- de Roodt, A, Paniagua-Solis, JF, Dolab, JA, et al. Effectiveness of two common antivenoms for North, Central and South American *Micrurus* envenomations. *J Toxicol Clin Toxicol* 2004;42:171–178.
- Marks, S, Mannella, C, and Schaer, M. Coral snake envenomation in the dog. Report of four cases and review of the literature. *J Am Anim Hosp Assoc* 1990;26:629–634.
- Peterson, ME. Snake bite: coral snakes. *Clin Tech Small An Pract* 2006;21(4):183–186.
- Wisniewski, MS, Hill, RE, Havey, JM, Bogdan, GM, and Dart, RC. Australian tiger snake (*Notechis scutatus*) and Mexican coral snake (*Micrurus* species) antivenoms prevent death from United States coral snake (*Micrurus fulvius fulvius*) venom in a mouse model. *J Toxicol Clin Toxicol* 2003;41:7–10.

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Snake Bite—Pit Vipers



DEFINITION/OVERVIEW

- Of over 120 species of snakes found in North America, 20 species are venomous.
- Venomous snakes in North America can be divided into two families: *Crotalidae* (pit vipers, including rattlesnakes, copperheads, and cottonmouths [water moccasins]) and *Elapidae* (i.e., coral snakes).
- Far and away the group responsible for both the greatest number of bites and the most serious bites are members of the family *Crotalidae*. Each year 99 percent of snake bites in the United States are initiated by crotalids.
- It is estimated that 150,000 dogs and cats are bitten each year in the United States by rattlesnakes, copperheads, and water moccasins.

Natural History

- *Crotalidae* are known as “pit vipers” because they possess a specialized, heat-sensing facial “pit” that aids them in locating and obtaining warm-blooded prey.
- In addition to the bilateral heat-sensitive pits between the eyes and nostrils, pit vipers display retractable fangs, elliptical pupils, triangular-shaped heads, and a single row of subcaudal scales caudal to the vent.
- There are three genera of *Crotalidae* in the United States, *Crotalus* (rattlesnakes), *Sistrurus* (pygmy rattlesnakes), and *Agkistrodon* (which are the rattleless copperheads and water moccasins).
- Venomous snakes are found in every state in the United States except Maine, Alaska, and Hawaii.
- Rattlesnakes do not always rattle before striking. Rattlesnakes can strike approximately one half their body length.
- Pit vipers can meter the amount of venom they release in a bite. “Offensive” bites on food objects release less venom than “defensive” bites against attackers. “Agonal” bites delivered by dying snakes can release all the venom they possess.



ETIOLOGY/PATHOPHYSIOLOGY

- Pit viper venom is a complex mixture of bioactive enzymes and peptides.

- Hyaluronidase (spreading factor) and collagenase aid in spreading venom through interstitial spaces.
- Proteases lead to coagulopathies and necrosis.
- Phospholipases cause cytotoxic effects that lead to inflammation and endothelial cell death.
- Pit viper venom increases the permeability of capillary cell membranes. Damage to the microvasculature allows erythrocytes and plasma to escape, resulting in both edema and ecchymosis.
- Plasma loss to edema and third spacing can result in hypotension.
- Enzymes and proteins in snake venoms can result in coagulopathy. Fibrinolytics and thrombin-like enzymes in venom result in depletion of fibrin and fibrinogen, decreased ability to form intravascular clots, elevated fibrin degradation products, and prolonged clotting tests.
- Snakebite coagulopathy is unique and differs from other forms. Unlike true DIC, pit viper coagulopathies have normal antithrombin and factor XIII levels.
- Thrombocytopenia is common in pit viper envenomations and is the result of phospholipase damaging platelet membranes triggering their destruction, venom-initiated platelet aggregation, and platelet consumption by inflammation at bite site.
- Renal failure can be seen secondary to crotalid envenomation. It is the result of hypotension, circulatory collapse, and toxic nephropathy of degradatory by-products.
- Neurotoxicity is primarily seen in envenomation by the Elapidae but neurological signs can be seen in bites by the Mojave rattlesnake (*Crotalus scutulatus*) of the southwestern United States. Other snakes may also possess some neurotoxic activity.
- The bite of young snakes is toxic; young snakes are reported to have higher percentages of toxic fractions. However, adult snakes inject larger amounts of venom.

Toxic Dose

- The amount of venom injected varies with the age, size, species, and motivation of the snake. Eastern and western diamondback venom yields can be as high as 800 mg whereas copperheads may yield only 40 mg.
- In general, rattlesnakes are more toxic than water moccasins (cottonmouths) which are more potent than copperheads.
- In terms of the LD₅₀ for rodents, the Mojave rattlesnake has the most toxic venom (although larger snakes and larger species release more venom).
- Pit viper bite severity is related to the volume and toxicity of the venom injected, the location of the bite on the victim, and the rate of its uptake.
- Victim-associated factors determining bite severity include: size of the victim, time elapsed between bite and initiation of treatment, and victim activity after bite occurs (activity increases venom absorption).
- An unknown percentage of crotalid bites are “dry” (non-envenomating).



CLINICAL FEATURES

- In dogs, the majority of bites occur on the head and face. In cats, bites occur to the thorax, abdomen and paws.
- The hallmark of crotalid envenomation is intense, rapid swelling (Figures 98.1 and 98.2). A bite can be considered “dry” if there are no signs after 1 hour.
- Clinical signs include fang marks, swelling, edema and considerable pain at the site. Other signs may include erythema, petechia, ecchymosis, and tissue necrosis.
- The signs of a localized bite can progress to systemic signs of vomiting, depression, respiratory distress, tachycardia, hypotension, fever, and coagulation abnormalities.
- Bites to the tongue can be particularly insidious.
- Fang marks can be quite inconspicuous and covered with fur.
- Swelling can be intense and is not merely edema, but is caused by extravascularized blood seeping from damaged blood vessel walls.
- Intense swelling can interfere with breathing and with swallowing. Animals may salivate profusely.
- Clinical signs general appear within 1 to 3 hours and progress rapidly.
- Tissue around the bite may quickly become badly bruised; swelling worsens the first 24 hours and may slough or ooze dark, watery blood.
- Cats have been reported to be more resistant (on a milligram of venom to a kilogram of body weight basis) to pit viper venom than dogs. However, cats are typically



■ **Figure 98.1** Facial swelling after envenomation by the prairie rattlesnake (*Crotalus viridis viridis*).



■ **Figure 98.2** Swelling of the paw after rattlesnake envenomation.

presented to hospitals in a more advanced clinical condition. Also, the severity of the bite is almost always inversely related to the victim's size.



DIFFERENTIAL DIAGNOSIS

- Differential diagnoses for pit vipers include: trauma, angioedema from arthropod bites or stings, other animal bite wounds, draining abscesses, and penetrating wounds.



DIAGNOSTICS

- At present there is no method available that can definitely establish that a pit viper envenomation has occurred and no way to measure the degree of that envenomation. Diagnosis must be based on history (knowledge of snakes in that area) and clinical signs.
- After envenomation laboratory abnormalities include echinocytosis, thrombocytopenia, anemia, hemoconcentration, elevated fibrin split products, hypofibrinogenemia, leukocytosis, and prolonged clotting times.
- Serial blood tests should be performed to monitor coagulopathies.
- Serum biochemical blood profile abnormalities include azotemia, hypoalbuminemia, hypoproteinemia, and elevated levels of creatine kinase, alkaline phosphatase,

alanine transaminase, gamma-glutamyl transpeptidase, and aspartate aminotransferase.

- Erythrocytes transformation into echinocytes (red blood cells with regular spiky membrane projections) has been described following snake bite envenomation in dogs, cats, and humans. The frequency of echinocyte formation has been reported to be 89 to 92 percent of dogs following snake bite envenomations.
- It has been suggested that the presence of echinocytes be used as a matter for envenomation in dogs; however, other disease processes can cause echinocytosis.



THERAPEUTICS

- Any animal suspected of being bitten by a venomous snake should be seen.
- Treatment interventions to be avoided include: ice, incision and suction, tourniquets and constriction bands, splints, hot packs, electroshock, and fasciotomy.
- Initial laboratory work performed should include: complete blood count (with erythrocyte morphologic analysis), a platelet count, biochemical profiles, coagulation profile (activated clotting time, prothrombin time, partial thromboplastin time, fibrinogen level), and a urinalysis. Perform ECG to monitor for arrhythmia.
- Clip and prep the affected area gently with an antiseptic solution, measure the circumference of swollen, bitten area to monitor progress of swelling.
- Due to the rapid onset of hypotension, victims of pit viper envenomation should begin to receive intravenous fluids (crystalloids: lactated Ringer's solution of 0.9% NaCl) upon admission to the hospital (30 ml/lb per day if stable, 90 ml/lb if in hypovolemic shock).
- Colloids appear adequate and beneficial in maintenance of vascular volume and colloid oncotic pressure.
- Goals of treatment include management of hypotension, venom neutralization, and pain management.
- The only proven specific therapy against pit viper envenomation is the administration of antivenin.
- Two antivenins are currently available in the United States: Antivenin (Crotalidae) and Polyvalent (ACP-Ft Dodge Animal Health). This antivenin acts by neutralizing venom in patients via passive immunization of globulins obtained from horses immunized with venom from several of the more common crotalids. The most significant adverse effect is anaphylaxis secondary to the equine source of the antivenin.
- The second, newer antivenin is Crotalidae polyvalent immune Fab (ovine: croFab, FabAV, Protherics, Nashville TN). It is an ovine derived product. Sheep are inoculated with venom from a variety of common crotalids. It is considered five times as potent as the equine products, appears effective in treatment of crotalid-induced neurotoxicity, and has fewer cases of anaphylaxis because it does not contain the complement-binding immunoglobulin portion. It is considerably more expensive than its equine predecessor and its use may be cost prohibitive.

- Antivenin functions best if given as soon after the bite as possible.
- Antivenin does not reverse tissue necrosis once it has occurred but additional damage can be prevented. Antivenin is extremely effective in reversing venom, induced thrombocytopenia.
- Skin testing for allergic reaction to equine antivenin is hard to evaluate because false-positives and false-negatives occur. Animals may be pretreated with diphenhydramine and monitored for allergic reaction (hyperemia of the inner pinna, pruritis, fluffing of the tail, etc.) as the product is given. If anaphylactic reactions occur they can be treated with histamine blockers, systemic corticosteroids, epinephrine and slowed or discontinued antivenin administration.
- Administration of the equine-derived product involves reconstituting the antivenin, delivering it into 100 to 200ml of intravenous fluids and administering it slowly over 30 to 60 minutes while monitoring for anaphylaxis.
- Antivenin should only be given intravenously and never injected into the bite. Antivenin uptake is delayed for 12 hours if given intramuscularly.
- The suggested dose of antivenin is one to five vials IV depending upon the severity of clinical signs, time since envenomation, size of the bite, and size of the patient. Studies indicate that smaller patients may require relatively higher dosages. Early administration of antivenin is more effective and one vial given early may be as effective as five vials given later.
- Pain management of snake bite victims is critical. Buprenorphine (0.01 mg/kg IV every 6 hours) or fentanyl (2–3 µg/kg IV then 1–5 µg/kg per hour CRI) may be employed. Monitor closely for respiratory depression.
- Antibiotic therapy following snake bites has fallen into disfavor. However, the wide range of pathogenic bacteria found in the mouths of snakes are a cause for concern. In humans and animals, the incidence of secondary wound infection in snake bite victims is quite low. Although antibiotics may be unnecessary in snake envenomation, they should still be considered until further studies are available. A broad-spectrum antibiotic would provide best coverage.
- Human studies have failed to document any benefits of corticosteroid administration in treating snake bite and are not routinely administered. They do not alter the course of the envenomation and may contribute to sepsis. Nevertheless, many veterinary researchers continue to advocate their use in anti-inflammatory doses as beneficial (prednisone, 0.5 mg/kg PO once daily for 5 days maximum).
- The “Extractor,” a venom suction device obtaining two atmospheres of suction pressure, is reported to be able to remove 30 percent of the venom if applied for 30 minutes immediately following the bite. Nevertheless, this is a very labor-intensive endeavor for such a small return.
- Emergency rooms treating snake bite victims must be prepared to perform urgent airway management (i.e., endotracheal tubes, tracheotomy kits, oxygen cages) particularly if the head, face, neck, or tongue are involved. Swelling can be rapid, progressive and dynamic.
- Later surgical debridement and repair of necrotic areas may be required.



COMMENTS

Prevention/Avoidance

- Keep dogs on leashes and closely supervised when in known or prime snake habitat.
- Similarly keep cats indoors in areas of high snake density.
- In areas of known rattlesnake abundance, snake avoidance classes are often offered to teach dogs to avoid contact with snakes.
- Dogs do not seem to learn about snakes. Several accounts have been reported of dogs being bitten in successive years.
- A *Crotalus atrox* toxoid rattlesnake vaccine (Red Rock Biologics) developed for prophylaxis against rattlesnake bite is now available. Two doses are initially given 1 month apart followed by a yearly booster. No canine studies on efficacy of this vaccine have been published and its effectiveness has not been documented. Further study is necessary before this vaccine can be deemed as effective.

Expected Course and Prognosis

- Prognosis for pit viper bite victims depends on the degree of envenomation, the type of snake, the location of the bite, and the time elapsed between the envenomation and initiation of therapy. The sooner emergency intervention is begun and the more aggressive the management, the better the outcome. Prognosis is worse for animals with severe hypotension, hematologic complications, and extremely small size. Nevertheless, if managed vigilantly, the vast majority of animal snake bite envenomation victims survive with no permanent sequelae.
- Severely affected animals may require administration of antivenin. For the most severely affected, those receiving antivenin have a much higher survival rate than those not receiving the medication.

Abbreviations

- CRI: constant rate infusion
- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- IV: intravenously
- LD50: lethal dose that kills 50 percent of animals tested
- NaCl: sodium chloride
- PO: by mouth

Suggested Reading

Camilleri, C, and Offerman, S. Anaphylaxis after rattlesnake bite. *Ann Emerg Med* 2004;43(6): 784–785.

- German, BT. Systemic effects of crotalid envenomation mislabeled as anaphylaxis. *Ann Emerg Med* 2005;45(1):101–102.
- Hackett, TB, Wingfield, WE, Mazzaferro, EM, and Benedetti, JS. Clinical findings associated with prairie rattlesnake bites in dogs: 100 cases (1989–1998). *J Am Vet Med Assoc* 2002;220(11):1675–1680.
- Moss, ST, Bogdan, G, Dart, RC, et al. Association of rattlesnake bite location with severity of clinical manifestations. *Ann Emerg Med* 1997;30(1):58–61.
- Peterson, ME. Snake bite: North American pit vipers. In: Peterson, ME, and Talcott, PA, eds. *Small Animal Toxicology*, pp. 1017–1038. W.B. Saunders, 2006.
- Peterson, ME. Snake bite: Pit vipers. *Clin Techn Small Anim Practice* 2006;21(4):174–182.
- Schaer, MS. Eastern diamondback rattlesnake envenomation of 20 dogs. *Comp Cont Ed* 1984;6(11):997–1007.
- Wiley, JR, and Schaer, M. Eastern diamondback envenomation of dogs: 31 cases (1982–2002). *J Am Anim Hosp Assoc* 2005;41(22):22–33.

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Spider Bite—Black Widow



DEFINITION/OVERVIEW

- Over 20,000 spider species are found in North America and all but two are venomous. However, only 50 of these species have fangs capable of penetrating mammalian skin. Furthermore, the majority of these spiders possess small quantities of venom and weak delivery systems that limit severe toxicity.
- The majority of spider bites are of no medical consequence or concern. Spider bites have not been shown to transmit communicable diseases; spider envenomations do not generally become secondarily infected; and allergic reaction following a spider bite is extremely rare.
- A few species produce much more toxic venoms capable of causing skin lesions, systemic illness, neurotoxicity, and death.
- Spider venoms are composed of complex proteins and proteolytic enzymes either designed to initiate digestion of prey entrapped by web spinners or to incapacitate prey ambushed by hunting spider.
- In general, hunting spiders such as brown recluse spiders (*Loxosceles* species), funnel-web spiders (*Atrax* and *Hadronyche* species), and South American armed spiders (*Phoebetreria* species) have more potent venoms than web spinners, with the notable exception of widow spiders (*Latrodectus* species).
- Some spiders, notably tarantulas, can use hind legs to launch urticating hairs from their dorsal abdomens to irritate the skin, eyes, and mucous membranes of pursuing attackers.
- Some reports state that you are never more than 1 meter away from a spider.

Natural History

- Widow spiders (*Latrodectus* species) are found in tropical and temperate latitudes worldwide (over 40 species identified), and 5 species reside in the United States in every state except Alaska. In the Continental United States the most common widow spider is *Latrodectus mactans* (black widow) (Table 99.1).
- Black widows prefer dark, dry, draftless areas. Preferred habitats include: brick and rock piles, wood piles, wall crevices, crawl spaces, gas and water meters, barns, stables, attics, closets, cupboards, trash piles, garages, basements, and outhouses.

TABLE 99.1 Medically Important *Latrodectus* Spiders in the United States

Latrodectus mactans (i.e., black widow, southern black widow)
Found throughout Continental United States, except Alaska

Latrodectus hesperus (western black widow)
Found in western United States

Latrodectus variolus (northern widow)
Found in northern parts of United States

Latrodectus bishopi (red widow, red-legged widow)
Found in central and southern Florida

Latrodectus geometricus (brown widow)
Found in Florida

- The majority of bites in humans occur during the colder months when the spiders come into human habitations. The rest of the year they live outdoors. These spiders construct funnel-shaped webs, irregularly shaped with a tattered appearance. They spin web “trip-wires” that may trail below their dark crevice retreats.
- Female black widows are larger, darker, and more venomous than the smaller males. Females have a 30- to 40-mm leg span (male leg span from 16–20 mm), but females can be as much as 20 times the size of males.
- Females can be 2 to 2.5 cm long and can cause life-threatening envenomations. Female black widows are dark gray to black and display the characteristic red or orange hourglass pattern on the ventral surface of her shiny, globous black abdomen. The hourglass becomes more prominent as the spider ages.
- Immature females are capable of delivering a severe envenomation, lack the typical swollen abdomen and hourglass of the adult female, and are red, brown, and beige. Immature females may take on the color of their last insert meal.
- Some females consume male mates after breeding giving the spider its name. Males rarely bite and their bite is of no medical significance.
- Black widow females are shy, non-aggressive, and retreat from drafts and large currents of air. Nevertheless, females will protect their egg sac and the web. Like the brown recluse, black widows are fairly long-lived and can live over 1 year.
- The five species of widow spiders found in the United States include *L. bishopi*, *L. geometricus*, *L. hesperus*, *L. variolus*, and *L. mactans*. The name *Latrodectus mactans* means “sneaky biter.”
- It should be remembered that spider bites can occur well outside the normal range, due to travel, commerce, and the innate ability of spiders to stow away.



ETIOLOGY/PATHOPHYSIOLOGY

- Black widows (*Latrodectus* species) produce one of the most potent venoms by volume.

- Through striated muscle control, these spiders can meter the amount of venom they inject with each bite. It has been estimated that 15 percent of bites are non-envenomating (dry).
- Clinical signs (latrotoxicism) from black widow bites are caused by a neurotoxic component of the venom, alpha-latrotoxin. This molecule causes massive presynaptic release of most neurotransmitters including acetylcholine, norepinephrine, dopamine, and glutamate.
- The alpha-latrotoxin targets the presynaptic neuronal membrane, which leads to the massive release of both calcium-dependent (catecholamines) and calcium-independent (acetylcholine, GABA, and glutamate) neurotransmitters.
- It appears to do this through formation of stable transmembrane pores, which allow calcium influx into the presynaptic nerve terminal.
- Initially stimulatory to end-plate action potentials, the neurotoxin later blocks neurotransmission through depletion of synaptic vesicle contents and then subsequent inhibition of neurotransmitter reuptake.
- Black widow spider venom is a primary neurotoxin; it contains no locally active peptides that provoke an inflammatory action at the site of envenomation.

Toxic Dose

- As opposed to the brown recluse spider, people report that the bite of the black widow spider is moderately painful.
- Black widow spider venom on a volume-to-volume basis is 100 times more potent than the venom of a pit viper. Fortunately, because their prey objects are primarily small insects only a small amount of venom is injected with each bite.
- It appears venom toxicity is increased in areas of higher environmental temperature and in bites occurring in the fall.
- For companion animals, a single bite can deliver a lethal envenomation.
- The brown widow (*L. geometricus*) has the most potent venom. The LD50 is 0.43 mg/kg body weight. The LD50 of the black widow is 1.39 mg/kg. The toxic fraction of the venom appears to be the same for the entire genus but varies in volume percentage between species.



CLINICAL FEATURES

- Clinical signs of latrotoxicism develop within 30 minutes to a few hours following the bite.
- Local tissue changes around the bite are absent or mild, swelling is uncommon, and a mild erythema may develop, which is easily missed due to tissue pigmentation and dense coats.
- More severe systemic manifestations depend on: size of the spider, motivation of the spider (how much venom injected), and time of year (altered venom potency). Also the location of the bite, the size, age, species, and general health of the spider's victim all contribute to the possible severity of the bite.

TABLE 99.2 Comparison of Widow Spider and Recluse Spider Bites

| Bite Characteristics | Widow (<i>Latrodectus</i>) Bites | Recluse (<i>Loxosceles</i>) Bites |
|----------------------------|------------------------------------|-------------------------------------|
| Initial bite: | Moderately painful | Painless |
| Mechanism of venom: | Massive neurotransmitter release | Local cytotoxicity |
| Predominant poison: | Alpha-lactotoxin | Sphingomyelinase D |
| Incubation period: | Rapid (1 hour) | Delayed (3 days) |
| Most common sign: | Muscle rigidity—spasms | Rash and lesion |
| Signs of systemic illness: | Fever, ataxia, paresthesia | Hemoglobinuria and renal failure |
| Outcome of most bites | Resolution in 2–3 days | Ulcers may take weeks to heal |

- Dogs and cats show severe pain, muscle cramping, vomiting, diarrhea, tremors (Table 98.2), and abdominal rigidity without tenderness.
- Respiratory distress may become evident and if death occurs it is usually due to respiratory collapse.
- Cats are extremely susceptible to the venom of black widow bites. Painful howling and vocalization can progress to ataxia and paralytic signs. Rhabdomyolysis and seizures are rare. Rarely are the small bite wound punctures identified.
- Envenomated animals can lose as much as 20 percent of their body weight in the first 24 hours following the bite.
- The muscle spasms, cramping, and abdominal rigidity are thought to be due to the massive release of neurotransmitters and an influx of sodium. Deaths can occur in cats, in smaller animals, and in compromised or debilitated animals.
- Rarely is the spider seen. Animals may vomit up the culprit spider. In our practice, a dead black widow was found between the lip and gingiva in a cat displaying signs similar to latrodectism.
- In one study, 20 of 22 cats envenomated by black widows died as a result of the bite.



DIFFERENTIAL DIAGNOSIS

- Differential diagnoses for black widow spider bites include acute abdomen, back pain from intervertebral disk disease, marijuana intoxication, bromethalin toxicity, macadamia nut poisoning, and various drug toxicities.



DIAGNOSTICS

- At present there is no diagnostic test for the presence of black widow venom.
- Unless the owners saw the spider, a history is generally not helpful in matching clinical signs to a cause.

- On physical examination due to dense hair coat and pigmentation the bite site is rarely discovered.
- Black widow spider bites only swell minimally and do not possess the dermonecrotic behavior sometimes associated with brown recluse bites.
- On complete blood count, black widow envenomations typically display a leukocytosis.



THERAPEUTICS

- Historically, a variety of treatments have been tried for black widow spider envenomations. Muscle relaxants, intravenous calcium gluconate, opioids and *Latrodectus*-specific antivenin have all been employed.
- Local wound care of *Latrodectus* bites should include: thorough wound cleansing, pain management, and an initial complete blood count and serum biochemistry profile. Urinalysis is recommended.
- Although calcium gluconate has been recommended in the past it has been shown to be ineffective for pain relief when compared to opioids, benzodiazepines, and *Latrodectus* antivenin.
- *Latrodectus* antivenin is indicated in patients manifesting severe regional or systemic toxicity and for animals displaying hypertension, seizures, or impending respiratory arrest.
- The older *Latrodectus* antivenin was produced from horses and could cause serum sickness, anaphylaxis, and death. The newer, purified Fab-fragment antivenins are now available in South America and Australia and have been shown to rarely cause immunologic complications.
- In the United States, antivenin is available, (Lyovac [*Lactrodectus*] antivenin, equine origin, Merck Sharpe and Dohme), but it should be reserved for severe envenomations. One vial is generally sufficient. Risk of allergic reaction to antivenin can be diminished by a pretreatment intradermal skin test of the antivenin or pretreatment injection of diphenhydromine (2–4 mg/kg SQ). Antivenin provides the fastest, most effective relief to the more severely affected individuals.
- If antivenin is not available, animals should be treated with aggressive wound management, intravenous fluids, and a combination of opioids and benzodiazepines for pain management.



COMMENTS

Expected Course and Prognosis

- Spider bites can be prevented in domestic animals by providing a clean, safe, hygienic environment. Clearing all litter and yard debris, restricting animals from woodpiles, regular household cleaning all cut down on prime spider habitat. Not allowing

animals unsupervised access to sheds, garages, attics, and basements can also reduce the number of bites. Finally, properly insulating houses, especially all windows, exterior doors, attics, and basement crawl spaces and by sealing all cracks and leaks with insulation material will do much to diminish spider numbers.

Abbreviations

- GABA: gamma-aminobutyric acid
- LD50: lethal dose that kills 50 percent of animals tested
- SQ: subcutaneously

Suggested Reading

- Clark, RE. The safety and efficacy of antivenin *Latrodectus maetans*. *J Toxicol/Clinic Toxicol* 2001;39:119–123.
- Clark, RE, Wethern-Kestner, S, Vance, MV, and Gerkin, R. Clinical presentation and treatment of black widow spider envenomation: a review of 163 cases. *Ann Emerg Med* 1992;21(7):782–787.
- Diaz, JH. The global epidemiology, syndromic classification, management, and prevention of spider bites. *Am J Trop Med Hyg* 2004;71(2):239–250.
- Diaz, JH, and LeBlanc, KE. Common spider bites. *Am Fam Phys* 2007;75(6):869–873.
- Frundle, TC. Management of spider bites. *Am Medical Journal* 2004;23(4):24–26.
- Isbister, GK, Graudins, A, White, J, and Warrell, D. Antivenom treatment in arachnidism. *J Toxicol/Clin Toxicol* 2003;41(3):291–300.
- Peterson, ME. Black widow spider envenomation. *Clin Tech Small Anim Pract* 2006;21(4):187–190.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Michael E. Peterson

Spider Bite—Brown Spiders



DEFINITION/OVERVIEW

- There are more than 30,000 species of spider worldwide, most of which are venomous.
- Most spiders cannot deliver serious bites due to delicate mouth parts and tiny fangs.
- Approximately 200 species from 20 genera worldwide can inflict severe envenomations on humans and animals causing discomfort, neurotoxicity, systemic toxicity, dermonecrosis, and death.
- The most medically important groups of biting spiders include the widow spiders (*Latrodectus* species), the recluse spiders (*Loxosceles* species), and two spiders confined to single countries: The Australian funnel web spider (*Atrax* and *Hadronyche* species) and the armed or banana spider (*Phoneutria* species) from Brazil (Table 100.1).
- Spider bites have not been shown to transmit communicable diseases and rarely trigger an allergic reaction.
- The collective term *arachnidism* is used to refer to envenomating spider bites; this includes all arachnids (i.e., scorpions, etc.). Envenomating spider bites are more correctly termed *araneism*. Spider bites can further be classified by systemic manifestations, such as necrotic araneism (for *Loxosceles* bites) and lactrodectism (for *Lactrodectus* or widow spider bites).
- Other species commonly implicated in the United States include *Cheirucanthium* spiders and *Tegenaria* species or hobo spiders.
- Some reports state that you are never more than 1 meter away from a spider.

Natural History

- *Loxosceles* spiders are the only globally distributed arachnid capable of causing necrotizing skin lesions.
- At least six species of *Loxosceles* in the United States are of medical importance.
- These include: *L. reclusa*, *L. laeta*, *L. arizonica*, *L. deserta*, *L. devia*, and *L. rufescens*. Other endemic *Loxosceles* spiders have minimal human and animal contact.
- All *Loxosceles* spiders are brown and aside from brown recluse have unique, identifying markings.
- Female brown recluse spiders are typically larger than males (20–30-mm leg span to a 10–35-mm leg span), are more venomous, and fawn to brown with an even darker

TABLE 100.1 Common North American Spiders of Minor Medical Importance

| Genus | Common Name |
|----------------------|-------------------------|
| <i>Araneus</i> | Orb weaver |
| <i>Argiope</i> | Garden spider |
| <i>Bothriocytrum</i> | Trap door spider |
| <i>Drussodes</i> | Mouse spider |
| <i>Herpyllus</i> | Parson spider |
| <i>Heteropoda</i> | Huntsman spider |
| <i>Liocranoides</i> | Running spider |
| <i>Lycosa</i> | Wolf spider |
| <i>Misumenoides</i> | Crab spider |
| <i>Neoscona</i> | Orb weaver, Barn spider |
| <i>Peucetia</i> | Lynx, Green Lynx spider |
| <i>Phiddipus</i> | Jumping spider |
| <i>Steatoda</i> | False black widow |
| <i>Ummidia</i> | Trap door spider |

distinctive pattern on the cephalothorax. In brown recluse females the unique pattern resembles a violin, fiddle, or cello with the base toward the head and the neck of the instrument pointed toward the abdomen. This design is the source of the name “fiddleback” spider.

- *Loxosceles* spiders are active at night and prefer warmer climates, with the majority of reported bites in the United States occurring south of Interstate 80.
- *Loxosceles* spiders are shy, build messy webs, and prefer dark, warm places such as rock piles, wood piles, attics, basements, closets, sheds, and trash receptacles.
- In humans, brown spider bites are reported to be initially painless or mildly stinging. This may be because bites most commonly occur at night and might not be felt by the sleeping victim.
- Most bites occur when the spider is trapped between the victim and clothing or bedding or are laid on.

Pathogenesis

- *Loxosceles* venom acts through a number of pathways and mediators. Sometimes it produces a dermonecrotic lesion and rarely severe systemic illness.
- The primary cytotoxic agent of *Loxosceles* venom has been identified as sphingomyelinase D, which activates complement, polymorphonuclear cells, and platelets.
- Hyaluronidase is also present and responsible for the spread of the lesion with gravity (a characteristic of *Loxosceles* envenomation).

- The remainder of the venom is composed of alkaline phosphatase, a variety of proteases, collagenase, esterase, ribonuclease, and deoxyribonuclease.
- Dermal histopathology of experimentally envenomated rabbits demonstrated edema of dermal endothelial cells, endothelial thickening, deposition of intravascular fibrin, and infiltration of inflammatory cells, particularly polymorphonucleocytes.
- Brown spider venom disrupts connective tissue basement membrane, stimulates release of large amounts of interleukin-8, monocyte-chemoattractant protein-1, and granulocyte-macrophage-colony-stimulating factor.
- All these substances amplify the inflammatory response accounting for the severe local reaction.
- Studies in humans and rabbits reveal that *Loxosceles* venom induces intravenous clotting, causing occlusion of dermal venules and arterioles adding to tissue hypoxia resulting in tissue necrosis.
- In particular, sphingomyelinase-D has been shown to induce platelet aggregation, consequent microvascular thrombosis, subsequently followed by ischemia and tissue necrosis. Sphingomyelinase-D makes up about 0.02 percent of the venom.
- The rare deaths reported from systemic illness result from disseminated intravascular necrosis and renal failure. Renal injuries result from *Loxosceles* toxins binding to glomerular and tubule cells.

Toxic Dose

- *Loxosceles* species vary in venom strength and vary with the size and sex of the spider involved. A full envenomation can deliver up to 0.07 mg of venom. A single bite can be lethal. *Loxosceles* venom acts through multiple pathways and mediators usually resulting in a painful bite area, sometimes producing a dermonecrotic lesion and occasionally causing severe systemic illness. It has been postulated that the systemic form and rare deaths are the result of renal failure and hemolysis. The degree of hemolysis can be profound. A lack of hemolysis essentially rules out systemic involvement.



CLINICAL FEATURES

- The initially relatively painless or mildly stinging bite is followed within 2 to 8 hours by painful blistering with surrounding erythema.
- The initial lesion progresses to one with a central darkness heralding pending necrosis surrounded by concentric edema (“bull’s eye” or “target sign”) within 24 to 48 hours.
- After 72 hours the lesion ulcerates in an eccentric pattern with eschar formation, slow healing, and scarring over the following weeks. In humans and rabbits, 15 days is average healing time.
- One hallmark of *Loxosceles* bites is this eschar thickens below the surface of the skin as opposed to other inflammation, infections, and non-spider-bite lesions, which raise above surrounding skin.

TABLE 100.2 Differential Diagnoses of Spider Bites

| |
|----------------------------------|
| Allergic contact dermatitis |
| Chemical burns |
| Trauma |
| Bacterial skin infections |
| Dermatomycosis |
| Other arthropod bites and stings |

- Transient physical signs may accompany *Loxosceles* bites. In humans, a general malaise, low-grade fever, nausea, vomiting, rashes, and general “flu-like” symptoms have been occasionally reported.
- Systemic illness is the most serious form of “*loxoscelism*,” involving hemolytic anemia, disseminated intravascular coagulation, thrombocytopenia and renal failure; however, this form is rare in both humans and animals bitten by brown spiders in North America.



DIFFERENTIAL DIAGNOSIS

- Ulcerating or necrotic wounds from a myriad of other insect-induced, infectious or physical sources are often misdiagnosed as brown spider bites.
- Causes of lesions that mimic dermonecrotic spider bites include thermal burns, bacterial infection and pyoderma, fungal infections, decubital ulcers, and neoplasia. Systemic illness must be differentiated from other causes of hemolysis (immune-mediated, zinc toxicity, onion poisoning) and fever of unknown origin.
- Brown spider bite is terrifically overdiagnosed and should not be used as a “speculative” diagnosis (Table 100.2).



DIAGNOSTICS

- Concrete diagnosis of *Loxosceles* spider bites is confounded by several factors including the extensive diagnosis of dermal bite-like lesions, suspected versus definite spider bites (eyewitnesses), and precise identification of the biting spider by arachnidologists.
- Anatomic location of spider bites appears to be far more dependent on the activity of the victim at the time of the bite rather than on the spider's typical behavior, preferred habitats, or feeding habits. Thus location of a spider bite is nondiagnostic.

- The diagnosis of brown recluse bites is frequently overused for dermonecrotic lesions of uncertain etiology, especially for locations in the United States where the spider is not even endemic.
- Factors affecting the severity of the bite include the sex of the spider, the size of the spider, and the size of the prey.
- Early attempts to diagnose brown spider envenomation involved passive hemagglutination inhibition tests measuring the venom's ability to inhibit the agglutination of venom sensitized erythrocytes. In guinea pigs, the test has 90 percent sensitivity and 100 percent specificity when conducted within 3 days of envenomation. The test is not widespread and is labor intensive and costly.
- The most accurate diagnostic test for *Loxosceles* envenomation is detection of either the venom itself or circulating antibodies to the venom.
- Sensitive *Loxosceles* species venom enzyme-linked immunosorbent assay has been developed for a variety of brown spiders but is not in widespread clinical use. No commercial tests are currently available in the United States.
- Another promising *Loxosceles* venom specific immunoassay being developed uses hair, skin biopsies, or tissue aspirates near a suspected lesion to detect the presence of venom up to 7 days post-envenomation. Presently this immunoassay likewise is not commercially available.
- Lymphocyte transformation has also been shown to be a specific indicator for envenomation, but it too is prohibitively labor intensive and costly.
- Although a variety of tests are promising, currently there is no gold standard diagnostic test for *Loxosceles* envenomation available in the United States.



THERAPEUTICS

- A definitive therapeutic approach to loxoscelism has yet to be established.
- A variety of interventions have been proposed including: dapsone, colchicine, surgical excision, steroids, and hyperbaric oxygen.
- The theoretical mechanism of action of polymorphonuclear cell inhibitors (such as dapsone and colchicine) is that they halt expanding dermonecrosis through inhibition of leukocyte migration, degranulation, and cytokine release.
- The effectiveness of leukocyte inhibitors such as dapsone has not been supported by clinical trials and poses a substantial risk of toxicity.
- One of the first interventions for cutaneous brown spider bites was surgical debridement and skin grafting. However, early surgical management has been found to be ineffective and often even harmful as an initial management.
- Spider bite wounds may take several days to weeks for the lesion to finally declare itself and demonstrate the area of necrosis and tissue destruction.
- In humans, only 3 percent of cutaneous loxoscelism victims require surgery or skin grafting and this usually because the lesion is greater than 2 cm or underlying problems such as peripheral vascular disease or diabetes mellitus impede primary healing.

The majority of *Loxosceles* envenomations result in little more than a mild inflammatory reaction. There is insufficient data to merit the use of corticosteroids for brown spider bites but the theoretical mechanism behind their use would be their immunosuppressive action blunting the response of the immune system to the bite. However, this type of beneficial activity has not been confirmed in clinical cases.

- Another possible intervention used in treatment of brown spider bites is the application of hyperbaric oxygen. The proposed mechanism of this treatment is the promotion of neovascularization and increased oxygen availability to ischemic tissue.
- Sphingomyelinase activity of the venom is not inhibited by hyperbaric oxygen and the majority of studies in animals showed no reduction in the amount of necrosis or lesion site. At present, there is no conclusive evidence to support the use of hyperbaric oxygen in treatment of loxoscelism.
- One study claimed hyperbaric oxygen therapy to be effective if administered within 6 hours of the envenomation. However, the majority of brown spider bites on animals are not recognized or treated until after 6 hours of the bite.
- The most important and effective intervention may be wound irrigation and aggressive wound management. Theoretically, the application of ice decreases damage and inflammation and prevents venom spread through vasoconstriction. Immobilization is also believed to decrease tissue loss but neither ice nor immobilization treatment efficacy has been confirmed in clinical studies.
- The application of heat and electric shock therapy of bitten areas have been shown to delay healing in animal studies.
- Topical application of nitroglycerin has been reported to decrease wound size, but controlled animal studies found no significant impact on lesion size using topical nitroglycerin at the envenomation site.
- Early *Loxosceles* bites are often diagnosed as infections explaining the widespread use of antibiotics. In humans, necrotic lesions generally are treated with antibiotics. Nevertheless, some authors believe that antibiotic coverage for a straightforward necrotic ulceration after brown spider envenomation is both unnecessary and inappropriate.
- There are four sources of *Loxosceles* antivenins, none of which are available currently in the United States. In Brazil, the antivenin is used in bites with large cutaneous lesions, extensive necrosis, and systemic illness. Depending on how soon it is administered it has been shown to decrease severity of reaction and shorten healing time. Nevertheless, in most animal species bite victims there is significant delay between the actual bite and presentation for treatment, which may diminish antivenin effectiveness. If animals present within 6 hours of envenomation spider bites may be more amenable to such interventions.
- Systemic loxoscelism is very rare and may be due to decreased renal function. Furthermore, secondary infections are most common in immunocompromised or diabetic animals. Animals displaying systemic signs should be hospitalized and intravenous fluids initiated to maintain hydration and protect renal function.
- In humans, wound care alone including debridement of necrotic tissues, culture-directed antibiotic therapy of secondary infections, and delayed assessment and

incision of eschars has proven to be a successful strategy. With proper wound management, brown spider envenomations heal within 1 to 8 weeks with a 10 percent chance of significant permanent scarring.



COMMENTS

Prevention/Avoidance

- The shy nature of *Loxosceles* species and a high tolerance to pesticides make extermination of the spider difficult. In addition, distribution of pesticides in households rarely reaches under the rocks and into woodpiles where brown spiders live. Furthermore, *Loxosceles* species do not have the foot pads through which other arachnids absorb pesticides. Multiple formulas have been tried but the brown spiders have shown resistance to most, even to exposure to dichlorodiphenyl-trichloroethane.
- Peak period of envenomation is the summer time.
- Bites often occur in beds when people and animals roll over on the spider during sleep.
- Cleaning dark, unused areas of the house decreases spider habitat.
- Decreasing insects that are the prey of the spider is another good preventative measure.
- Pulling beds away from walls is yet another good preventative.
- All suspected biting spiders should be brought in for identification by an expert so that interventions can be initiated before the appearance of a lesion.
- Animals should not be confined to areas of prime spider habitat.

Expected Course and Prognosis

- The treatment of brown spider envenomation continues to be hampered by the time-dependent nature of cellular damage. Nevertheless, the window of opportunity for effective treatment may be longer than previously thought.
- Early and aggressive wound management may be the most effective intervention.
- Dermonecrotic wounds of uncertain origin are often attributed to a brown spider bite. Thus such bites are overdiagnosed including areas where the spiders are rare or not even found. Misdiagnosis of these wounds can lead to delays in appropriate care, adverse outcomes, and increased medical legal risk, particularly if there is specific treatment for the actual underlying condition.
- The majority of brown recluse bites heal uneventfully in 1 to 3 weeks. A small percentage may require surgical intervention and result in significant scarring. An even smaller number of bites lead to systemic illness and even more rarely death. So the overall outcome of brown spider bites is favorable.

Suggested References

Diaz, JH, and LeBlanc, KE. Common spider bites. *Am Fam Phys* 2007;75(6):869–873.

Frundle, TC. Management of spider bites. *Am Med J* 2004;23(4):24–26.

Isbister, GK, Graudins, A, White, J, and Warrell, D. Antivenom treatment in arachnidism. *J Toxicol/Clin Toxicol* 2003;41(3):291–300.

Peterson, ME. Brown spider envenomation. *Clin Tech Small Anim Pract* 2006;21(4):191–193.

Wright, SW, Wrenn, KD, Murray, L, and Seger, D. Clinical presentation and outcome of brown recluse spider bite. *Ann Emerg Med* 1997;30:28–32.

Author: Kevin T. Fitzgerald

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Michael E. Peterson

Spinal Fracture



DEFINITION/OVERVIEW

- Fracture, subluxation, or luxation of the spine causing concussive or compression injury to the spinal cord



ETIOLOGY/PATHOPHYSIOLOGY

- Fractures/luxations—commonly at atlantoaxial, atlanto-occipital, cervicothoracic, thoracolumbar, and lumbosacral junctions
- Primary injury—initial compressive or concussive injury to the spinal cord
- Secondary injury—includes spinal cord swelling, ischemia, hemorrhage, edema, and decreased spinal cord blood flow; mediated by endorphins, catecholamines, free radicals, and excitatory neurotransmitters

Systems Affected

- Nervous—Signs range from pain to paralysis without deep pain sensation
- Musculoskeletal—Variable based on location and severity of lesion



SIGNALMENT/HISTORY

- Dogs and cats

Historical Findings

- Trauma—Hit by car most common
- Unknown—Acute paralysis or neurologic signs



CLINICAL FEATURES

- Initial physical and neurologic examination should be conducted prior to analgesia and sedation.
- Spinal pain; hyperesthesia

- Ataxia to non-ambulatory
- Palpable spinal deformity
- Neurologic examination based on lesion location; may have signs of spinal shock
- Schiff-Sherrington
- Often other signs of trauma



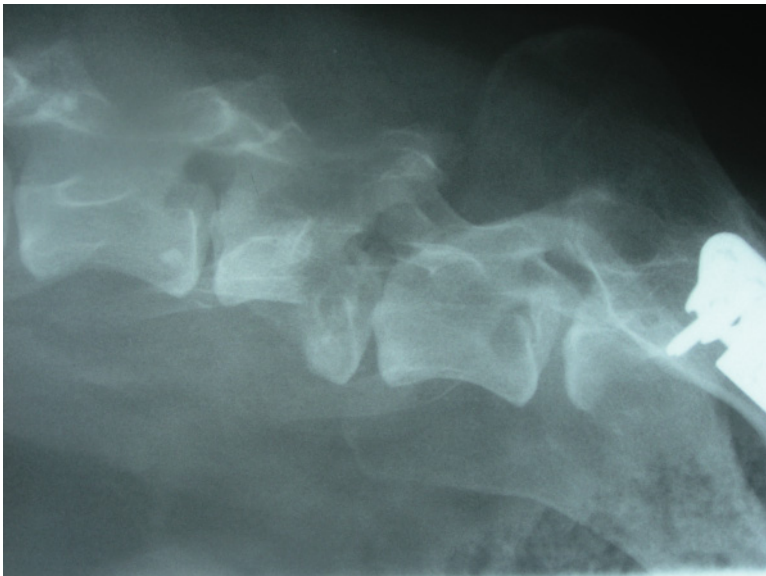
DIFFERENTIAL DIAGNOSIS

- Schiff-Sherrington phenomenon
- Myelomalacia; continuous or discontinuous
- Spinal cord compressive lesions; intervertebral disc disease, tumor, hemorrhage, edema
- Fibrocartilaginous embolism
- Spinal shock



DIAGNOSTICS

- Radiographs—survey radiographs of the entire spine to determine severity and locations; multiple lesions common
 - Sedation/general anesthesia may be necessary for a good radiographic study; caution that voluntary paraspinal muscle contraction will be lost and the spine may become more unstable
 - Lateral and horizontal beam



■ **Figure 101.1** Lateral radiograph of a dog with a vertebral body fracture of L6.



■ **Figure 101.2** Ventrodorsal radiograph of a dog with a vertebral body fracture of L6. This dog previously had a TPO for hip dysplasia.

- Myelography, CT, and MRI—detect spinal cord lesion
- Radiographs show the current amount of displacement, not the amount of displacement that occurred at the time of the injury (Figures 101.1 and 101.2).



THERAPEUTICS

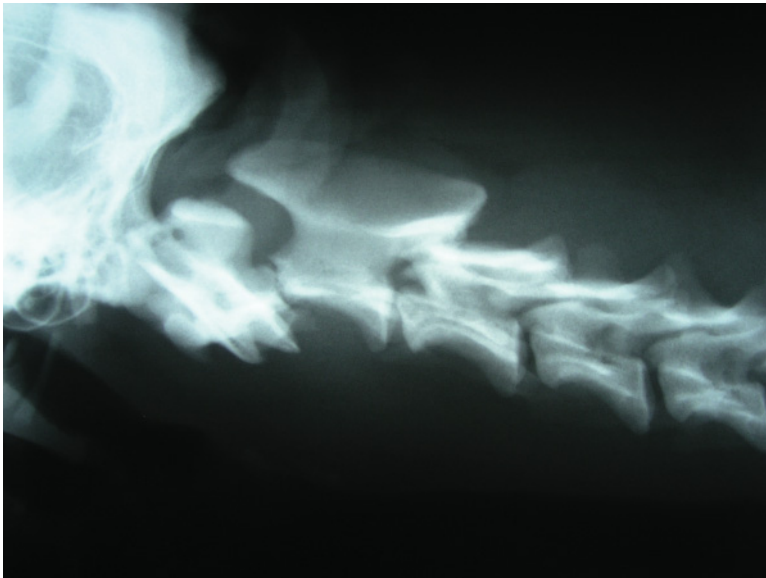
- The objective is immediate spinal cord stabilization (Figure 101.3) to prevent additional trauma during diagnosis and treatment of life-threatening conditions.
- Treat all life-threatening conditions.
- Maintain mean arterial blood pressure over 85 mmHg to increase spinal cord perfusion.
- Medical management: used in a stable spine with minimal spinal cord compression and stable neurologic signs
 - Splint/bandage stabilization; if cranial cervical, bandage should extend over the head to the eyes (Figures 101.4 and 101.5)
 - Cage rest 4 to 6 weeks
 - Monitor temperature if bandage is large.

Drug(s) of Choice

- Corticosteroids: Methylprednisolone sodium succinate (given within 8 hours of injury): 30 mg/kg IV initial dose, given slowly, 15 mg/kg IV 2 hours later, 15 mg/kg IV 4 hours later, followed by 2.5 mg/kg CRI for 42 hours



■ **Figure 101.3** Management of the patient with spinal trauma involves providing complete immobilization by securing the animal's head and shoulders and hips to a fixed firm surface, to prevent movement and further damage to the spinal cord if fracture or luxation/subluxation is present.



■ **Figure 101.4** Fracture of the dens of C2. The patient was ambulatory with no neurologic deficits and had presented on emergency for neck pain.



■ **Figure 101.5** Conservative medical management of a patient with dens fracture of C2. Note that the splint is extended over the animal's head to prevent movement of the head and neck.

- NSAIDs: (Dogs) Carprofen 2.2 mg/kg PO every 12 hours, 4 mg/kg SQ once; (Cats) Meloxicam 0.1 mg/kg PO every 24 hours four times daily, 0.3 mg/kg IV or SQ once
- Opioids: Hydromorphone 0.05 to 0.2 mg/kg IV, IM, or SQ every 2 to 4 hours; Tramadol 1 to 4 mg/kg PO every 8 to 12 hours
- Gastroprotectants: Famotidine 0.5 to 1 mg/kg IV or PO every 12 hours
- The use of steroids in acute spinal cord trauma is controversial and is unlikely to be helpful after 8 hours post-injury.

Precautions/Interactions

- Do not combine corticosteroids and NSAIDs.
- Corticosteroids are contraindicated in head trauma.
- Corticosteroids may increase the risk of gastric ulcers, sepsis, wound infection, and respiratory complications in these patients.
- Caution with NSAIDs in dehydrated patients.

Activity

- Immobilization—stabilize on a board or gurney using straps or tape that will allow for treatments and diagnostics with limited movement of the spine
- Cage rest for 4 to 6 weeks if medically managed

Surgical Considerations

- May be indicated for an unstable spine with spinal cord compression

- Internal or external fixation—to be determined by the surgeon
- Decompression



COMMENTS

Client Education

- Neurologic signs may progress.
- Discuss intense physical therapy and rehabilitation requirements after discharge.

Patient Monitoring

- Neurologic examination every 1 to 2 hours for change
- Blood pressure
- Patient rotation every 4 hours if spine is stable

Possible Complications

- Progression of neurologic signs
- Decubital ulcers
- Gastrointestinal ulceration with steroid use

Expected Course and Prognosis

- Prognosis is based on the underlying trauma and the presence or absence of deep pain.
 - Loss of deep pain <48 hours, <50 percent chance of recovery
 - Loss of deep pain >48 hours, condition is grave
 - Loss of deep pain with 100 percent vertebral displacement, virtually no chance of walking

Abbreviations

- CRI: constant rate infusion
- CT: computed tomography
- IM: intramuscularly
- IV: intravenously
- MRI: magnetic resonance imaging
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- SQ: subcutaneously

See Also

- Spinal Shock
- Schiff-Sherrington

Suggested Reading

Bagley, RS. Spinal fracture or luxation. *Vet Clinics N Am, Small Anim Pract* 2000;30:133–153.

Sharp, NJH, and Thomas, WB. How do I treat? Spinal fracture due to external trauma. *Prog Vet Neurol* 1996;7:29–32.

Smith, PM, and Jeffery, ND. Spinal shock—Comparative aspects and clinical relevance. *J Vet Intern Med* 2005;19:788–793.

Author: Stacy D. Meola

Spinal Shock



DEFINITION/OVERVIEW

- The loss of muscle tone and segmental spinal reflexes caudal to a severe spinal cord injury



ETIOLOGY/PATHOPHYSIOLOGY

- Acute spinal cord trauma—usually a solitary lesion; however, spinal shock can give the appearance of a multifocal lesion
- Poorly understood in companion animals—likely a sudden interruption in descending supraspinal input
- Should be suspected with flaccid paralysis and sudden return of reflexes in a quicker than expected recovery period
- May only last 30 to 60 minutes

Systems Affected

- Nervous—lesion localization is initially difficult to establish; loss of reflexes and muscle tone caudal to an acute spinal cord injury with rapid return of reflexes
- Musculoskeletal—paralysis, decreased muscle tone



SIGNALMENT/HISTORY

- Dogs and cats—rare; likely underreported

Historical Findings

- Trauma—hit by car most common
- Unknown—acute paralysis or neurologic signs



CLINICAL FEATURES

- Initial physical and neurologic examination should be conducted prior to analgesia and sedation.

- Non-ambulatory
- Areflexia
- Flaccid paralysis—below the lesion
- Flaccid bladder with urinary retention
- Neurologic examination may suggest multiple lesions; subsequent examinations should reveal rapid return of reflexes caudal to the lesion that are often exaggerated.
- Often other signs of trauma



DIFFERENTIAL DIAGNOSIS

- Schiff-Sherrington phenomenon
- Myelomalacia; continuous or discontinuous
- Spinal cord compressive lesions; intervertebral disc disease, tumor, hemorrhage, edema
- Fibrocartilaginous embolism
- Spinal fractures, luxations



DIAGNOSTICS

- Radiographs—lateral and horizontal beam
- Myelography, CT, MRI—detect spinal cord lesion



THERAPEUTICS

- The objective is immediate spinal cord stabilization to prevent additional trauma during diagnosis and treatment of life-threatening conditions.
- Intravenous crystalloid fluid: Initial shock rate (dogs) 90 ml/kg per hour, (cats) 44 ml/kg per hour bolus, give in one-fourth-dose increments
- Intravenous colloid fluid: to maintain blood pressure; Hetastarch 5 to 10 ml/kg bolus over 10 to 15 min
- Maintain mean arterial blood pressure over 85 mmHg to increase spinal cord perfusion.
- Urinary catheter—based on bladder function; may be useful to increase hygiene

Drug(s) of Choice

- Corticosteroids: Methylprednisolone sodium succinate (given within 8 hours of injury): 30 mg/kg intravenous initial dose, given slowly, 15 mg/kg IV 2 hours later, 15 mg/kg IV 4 hours later, followed by 2.5 mg/kg CRI for 42 hours
- NSAIDs: (Dogs) Carprofen 2.2 mg/kg PO every 12 hours, 4 mg/kg SQ once; (Cats) Meloxicam 0.1 mg/kg PO every 24 hours four times daily, 0.3 mg/kg IV or SQ once

- Opioids: Hydromorphone 0.05 to 0.2mg/kg IV, IM, or SQ every 2 to 4 hours; Tramadol 1 to 4mg/kg PO every 8 to 12 hours
- Gastroprotectants: Famotidine 0.5 to 1 mg/kg IV or PO every 12 hours
- The use of steroids in acute spinal cord trauma is controversial and is unlikely to be helpful after 8 hours post-injury.

Precautions/Interactions

- Do not combine corticosteroids and NSAIDs.
- Corticosteroids are contraindicated in head trauma.
- Corticosteroids may increase the risk of gastric ulcers, sepsis, wound infection, and respiratory complications in these patients.
- Caution with NSAIDs in dehydrated patients

Activity

- Immobilization—stabilize on a board or gurney using straps or tape that will allow for treatments and diagnostics with limited movement of the spine

Surgical Considerations

- May be indicated for spinal stabilization or spinal cord decompression



COMMENTS

Client Education

- Complete neurologic assessment and lesion localization may not be possible for several days.

Patient Monitoring

- Neurologic examination every 1 to 2 hours for change
- Blood pressure
- Patient rotation every 4 hours if spine is stable

Possible Complications

- Pressure sores
- Gastrointestinal ulceration with steroid use

Expected Course and Prognosis

- Return of reflexes after experimental spinal cord transection
- Anal sphincter reflex—15 min
- Patellar reflex—30 minutes to 2 hours
- Flexor withdrawal reflex—up to 12 hours

- Spasticity/hyper-reflexia—within 24 to 48 hours
- Crossed extensor reflex—1 to 2 weeks
- Prognosis is based on the underlying trauma and the presence or absence of deep pain, the presence of spinal shock does not change the overall prognosis

Abbreviations

- CT: computed tomography
- IM: intramuscularly
- IV: intravenously
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Lanz, O, Bergman, R, and Shell, L. Initial assessment of patients with spinal cord trauma. *Vet Med Symposium* 2000;Nov:851–853.

Smith, PM, and Jeffery, ND. Spinal shock—Comparative aspects and clinical relevance. *J Vet Intern Med* 2005;19:788–793.

Author: Stacy D. Meola

Splenic Torsion



DEFINITION/OVERVIEW

- May also occur as a separate entity as acute or chronic form
- Isolated splenic torsion is uncommon.



PATHOPHYSIOLOGY/ETIOLOGY

- Unknown
- Torsion mechanically compresses the thin-walled splenic veins, resulting in vascular congestion, arteries become occluded with thromboemboli and resultant infarction.

Systems Affected

- Cardiovascular and hemic/lymphatic/immune



SIGNALMENT/HISTORY

- More common in large-breed, deep-chested dogs, such as German shepherds, standard poodles, Great Danes, and retrievers
- No age predilection
- Males more affected than females



CLINICAL FEATURES

Historical Findings

- Acute—cardiovascular collapse and abdominal pain
- Chronic—duration of clinical signs up to months, intermittent anorexia, vomiting, weight loss, and possibly hemoglobinuria

Physical Examination Findings

- Acute—Pale mucous membranes, tachycardia, and other signs of hypoperfusion and shock
- Discomfort, acute abdominal pain
- Retching, drooling, weakness
- Possible palpable abdominal mass (spleen) depending on duration of torsion and abdominal splinting
- Chronic—Vague signs, depression, lethargy

Risk Factors/Causes

- Large breed and deep-chested dogs
- Prior stretching of gastrosplenic, phrenicosplenic, and splenocolic ligaments (e.g., prior gastric dilatation and volvulus)
- Historical gastric dilatation
- Excessive exercise, rolling, and retching may contribute.
- Nervousness and anxiety have been associated with an increased risk of GDV.



DIFFERENTIAL DIAGNOSIS

- Other splenic disease (e.g., neoplasia especially, hemangiosarcoma, trauma, hematoma and immune-mediated disease)
- Acute gastrointestinal disease with abdominal pain
- GDV
- Other midabdominal masses (e.g., gastrointestinal, pancreatic, and renal)
- Other causes of intravascular hemolysis



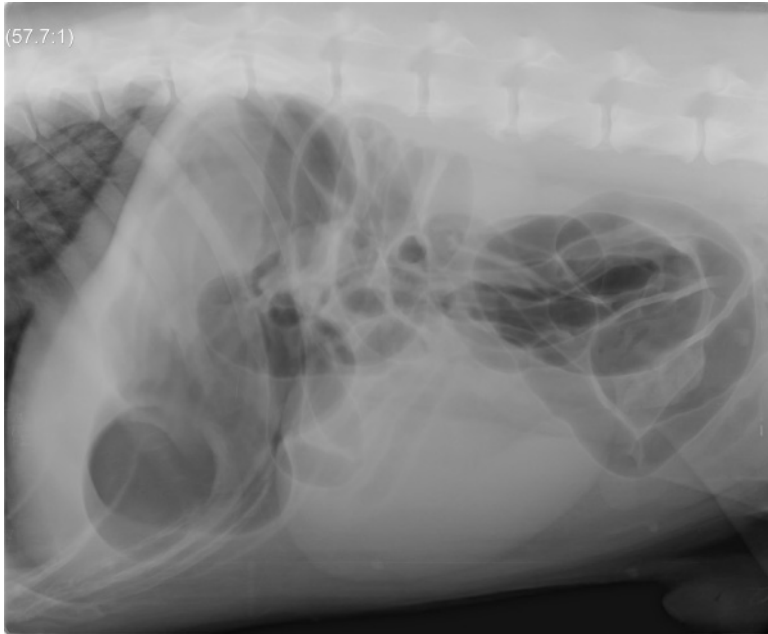
DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Acute—blood work generally not helpful
- Chronic—variable changes
- Anemia
- Thrombocytopenia
- Leukocytosis
- Elevated hepatocellular and cholestatic hepatic enzymes
- Elevated amylase and/or lipase
- Hemoglobulinuria

Other Laboratory Tests

- Coagulation test—DIC (prolonged prothrombin time, partial thromboplastin time, and increased fibrin degradation products) because of accelerated consumption.



■ **Figure 103.1** Lateral abdominal radiograph of a dog with splenic torsion. Note the large soft tissue density in the midabdomen that pushes the intestinal loops dorsally. Differential diagnosis for this also includes splenic mass.

Imaging

Abdominal Radiography

- Cranial or midabdominal mass may be seen (Figure 103.1).
- Spleen may be abnormally located, misshapen, multifocal gas opacities.
- Displacement of gastrointestinal tract
- Loss of abdominal detail (possible)

Abdominal Ultrasonography

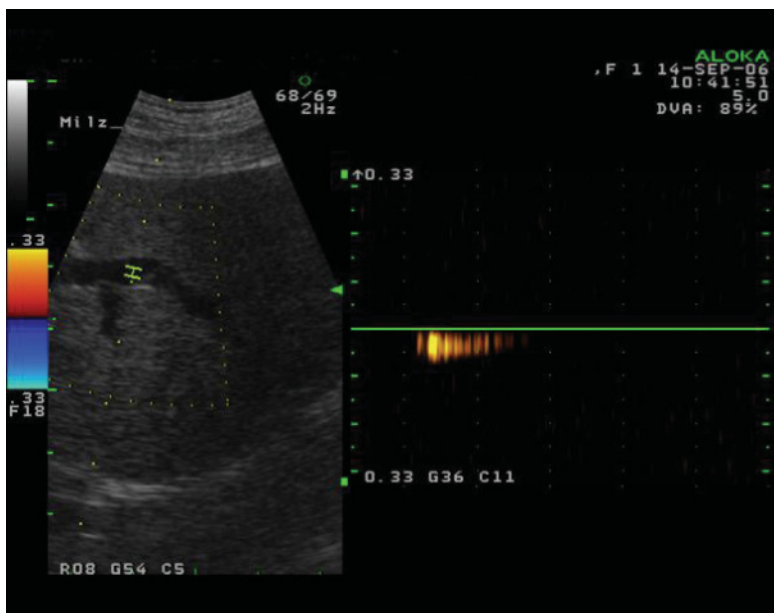
- Splenic congestion, splenomegaly
- Dilated splenic veins (multiple parallel echogenic lines)
- Diffuse hypoechoic areas with linear echoes separating large, anechoic areas (Figure 103.2)
- Splenic infarction
- No blood flow (absent velocity) in splenic veins with Doppler ultrasonography (Figure 103.3)
- Visible splenic vein intraluminal echogenicities are compatible with thrombi.

Diagnostic Procedures

- ECG—may show ventricular dysrhythmias.



■ **Figure 103.2** Ultrasound image of spleen that has undergone torsion. Note that the spleen appears hypoechoic.



■ **Figure 103.3** Doppler ultrasound image of a spleen with no blood flow in the splenic arteries, consistent with splenic torsion or thrombosis.

Pathologic Findings

- Splenic congestion and infarction

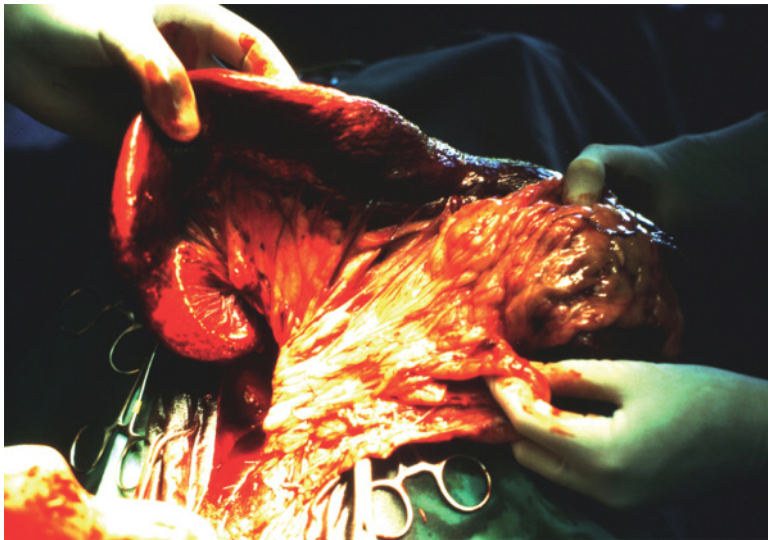


THERAPEUTICS

- Surgical emergency
- Anesthesia—avoid barbiturates, acepromazine, or other drugs that can cause splenic congestion
- Surgery—After adequate cardiovascular stabilization, a splenectomy should be performed without untwisting the splenic pedicle (Figure 103.4).
- Derotation of an acute torsion without splenectomy might be possible but is not recommended.
- Avoid ligation of pancreatic vascular supply by vessel ligation close to the spleen.
- The vascular pedicle cannot be untwisted in the chronic form due to fibrosis, thrombosis, and risk of splenic rupture.
- A permanent gastropexy may also be performed concurrently in a stable patient because of the association with GDV syndrome.
- Submit a portion of the spleen for histopathologic examination.
- Fluid support and cardiovascular monitoring indicated after splenectomy.

Drug(s) of Choice

- No specific drugs required.



■ **Figure 103.4** Intraoperative photo of splenic torsion. The spleen should be removed without untwisting the torsed pedicle.

- Postoperative analgesia
- Plasma transfusion may be considered if DIC and coagulopathy are documented.



COMMENTS

- Surgical correction is considered curative.
- Delayed treatment might lead to splenic necrosis, peritonitis, DIC, and sepsis.

Abbreviations

- DIC: disseminated intravascular coagulation
- ECG: electrocardiogram
- GDV: gastric dilation and volvulus

Suggested Reading

Neath, P, Brookman, DJ, and Saunders, HM. Retrospective analysis of 19 cases of isolated torsion of the splenic pedicle in dogs. *J Small Anim Pract* 1997;38:337–392.

Stoneham, A, Henderson, A, and O'Toole, T. Resolution of severe thrombocytopenia in two standard poodles with surgical correction of splenic torsion. *J Vet Emerg Crit Care* 2006;16:131–135.

Author: David Spreng

Acknowledgment to original author in Blackwell's Five-Minute Veterinary Consult: Canine and Feline: Elizabeth Rozanski

Supraventricular Tachycardia (SVT)

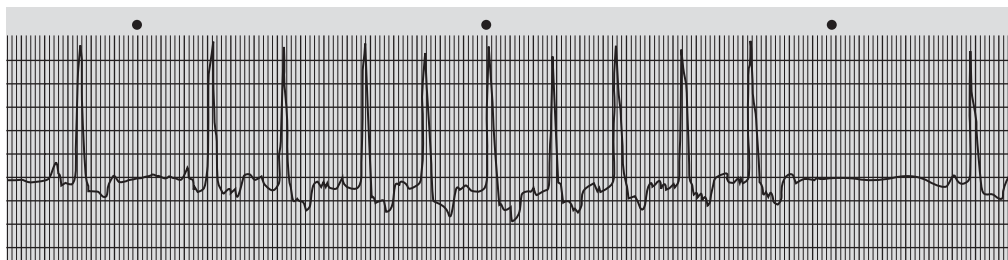


DEFINITION/OVERVIEW

- Repetitive supraventricular premature depolarizations that originate from a site other than the sinus node, such as the atrial myocardium or atrioventricular nodal tissue

Electrocardiogram Features

- Heart rate—rapid, 150 to 350 beats per minute in dogs. The lower rate of SVT depends on the size of the patient. Smaller dogs typically have higher sinus nodal rates than larger dogs.
- Rhythm usually very regular (R-R interval is constant) and may be sustained, but there can be frequent or infrequent short runs of SVT, so-called paroxysmal SVT. Rarely, the rhythm during the tachycardia will be irregular, suggesting abnormal automaticity as the etiology (Figure 104.1).
- Usually the QRS complexes are typical of normal sinus complexes, narrow with a normal mean electrical axis. In some cases a coexisting bundle branch block or aberrant ventricular conduction makes it difficult, if not impossible, to differentiate an SVT from a ventricular tachycardia by examining the ECG.
- P waves can be normal or abnormal and typically differ in configuration from the sinus P waves. P waves may be buried in the previous T wave and therefore not visualized.



■ **Figure 104.1** Sinus with an atrial premature complex and paroxysmal supraventricular tachycardia. Abrupt initiation and termination of the tachycardia help distinguish it from sinus tachycardia (lead II, 50 mm/sec, 1 cm = 1 mV).

Source: Tilley LP: *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Baltimore: Williams & Wilkins, 1992, with permission.

- Atrioventricular conduction is usually normal (1:1), but various levels of functional second-degree AV block may occur at higher atrial rates (2:1, 3:1, 4:1, etc).



ETIOLOGY/PATHOPHYSIOLOGY

- SVT may be primary (idiopathic) or secondary to other cardiac disease, generally those creating atrial enlargement.
- May result from a reentrant mechanism or from abnormal automaticity in an ectopic focus.
- Reentrant SVT typically produces a very regular rhythm; SVT due to an automatic focus in atrial myocardium can produce an irregular rhythm.
- Most cases in dogs respond to drugs that specifically alter conduction and refractoriness in the AV nodal tissue, suggesting AV nodal reentry as the mechanism.
- Recent electrophysiologic studies revealed that some SVT in dogs is related to a congenital accessory pathway between the atria and ventricles that allows the electrical impulses to travel freely between the atria and ventricles without traversing the AV node and without conduction delay; in these patients, the SVT is caused by reentry through the accessory pathway and the AV node.

Risk Factors/Causes

- Chronic valvular disease
- Cardiomyopathy
- Congenital heart disease
- Cardiac neoplasia
- Systemic disorders
- Ventricular preexcitation
- Electrolyte imbalances
- Digoxin toxicity
- Idiopathic

Systems Affected

Cardiovascular

- CHF may develop secondary to progressive myocardial failure associated with a chronically high heart rate (so called tachycardia-induced myocardial failure).

Neuromuscular

- Syncope or generalized episodic weakness due to reduced cardiac output and oxygen delivery

Genetics

- Labrador retrievers are suspected, on the basis of clinical data, to have a genetic predisposition to congenital accessory pathway.



SIGNALMENT/HISTORY

Species

- Dogs and rarely cats

Breed Predilections

- Labrador retrievers are overrepresented in the literature.

Risk Factors/Causes

- Heart disease
- Genetics in Labrador retrievers

Historical Findings

- Owners are generally unaware of the arrhythmia.
- Coughing or breathing abnormalities in dogs with CHF
- Episodic weakness or syncope



CLINICAL FEATURES

- Abnormalities noted on physical examination.



DIFFERENTIAL DIAGNOSIS

- Sinus tachycardia
- Atrial flutter
- Atrial fibrillation
- Ventricular tachycardia (SVT with right bundle branch block or aberrant conduction can look like ventricular tachycardia; resolution of arrhythmia after lidocaine administration usually confirms ventricular tachycardia)

Physical Examination Findings

- Rapid, usually regular heart rhythm. However, in dogs with paroxysmal SVT the rhythm may be normal and regular during the physical examination.
- May have evidence of poor peripheral perfusion: pale mucous membranes, a prolonged capillary refill time, and weak pulses
- May have no signs other than the rapid heart rate
- Findings may reflect an underlying cardiac condition (e.g., heart murmur).



DIAGNOSTICS

Imaging

- Echocardiography (including Doppler studies) may help characterize the type and severity of underlying cardiac disorders. Echocardiography is also important for assessing myocardial function in patients with idiopathic SVT.
- When viewed on an echocardiogram during bursts of SVT, the left ventricle has a normal end-systolic diameter and a small end-diastolic diameter, resulting in a decreased shortening fraction because of inadequate filling.
- Usually left or right atrial enlargement in dogs with SVT secondary to other cardiac disorders

Diagnostic Procedures

- Long-term ambulatory (Holter) recording of the ECG may detect paroxysmal SVT in cases of unexplained syncope. This is generally only helpful if the syncope is occurring regularly within a 24- to 48-hour period. Holter monitors may also help characterize the rate and frequency of sustained SVT and are useful in evaluating the efficacy of therapy.
- Event (Loop) recorders may detect paroxysmal SVT in patients with infrequent episodes of syncope (< every 24–48 hours).
- Sustained SVT must be distinguished from sinus tachycardia because the two arrhythmias have different implications and treatment. A precordial thump may help differentiate sinus tachycardia from SVT when the heart rate is in the 150 to 250 beats-per-minute range; it will usually stop an SVT for at least 1 or 2 beats, while a sinus tachycardia will not slow. A vagal maneuver (e.g., ocular pressure or carotid sinus massage) may break an SVT abruptly but only gradually slows sinus tachycardia.



THERAPEUTICS

Drug(s) of Choice

Emergency Therapy

- Administer one of the following drugs:
- Calcium channel blockers: verapamil (0.05 mg/kg boluses IV over 3–5 minutes up to three times) or diltiazem (0.05–0.25 mg/kg IV over 5–15 min)
- β -Adrenergic blockers: esmolol (0.25–0.5 mg/kg slow IV bolus administration followed by a constant-rate infusion of 50–200 μ g/kg per minute); moderate-to-severe myocardial failure is a relative contraindication to the administration of these drugs at these doses.
- Electrical cardioversion or intracardiac electrophysiologic pacing methods may be considered in extreme cases.

Long-Term Therapy

- Digoxin: administer at either a maintenance oral dose or double the maintenance dose for the first day to produce a therapeutic serum concentration more rapidly; contraindicated in patients with accessory pathways
- β -Adrenergic blocker; atenolol (0.2–1 mg/kg PO every 12 to 24 hours) can be administered as long as the patient does not have underlying moderate-to-severe myocardial failure.
- Diltiazem is the calcium channel blocker of choice for long-term control of SVT. The dosage required to control SVT has not been reported in the dog. Diltiazem is used more frequently to control the ventricular rate in patients with atrial fibrillation at a dosage of 0.5 to 1.5 mg/kg PO every 8 hours. Generally start in this dosage range but almost always increase the dose to 2.0 to 3.0 mg/kg PO every 8 hours to effect control of SVT.
- Class I antiarrhythmic agents such as quinidine and procainamide can be tried when the aforementioned drugs are ineffective or when the SVT is thought to be due to an automatic, rather than a reentrant, rhythm. SVT caused by an automatic atrial focus may produce an irregular rhythm and may be refractory to conventional drug therapy. When the SVT is due to an accessory pathway, these drugs are more effective.

Precautions/Interactions

- Calcium channel blockers and β -adrenergic blockers have negative inotropic properties and should be used cautiously in dogs with documented myocardial failure.

Alternative Drugs

- Emergency treatment: intravenous adenosine (1–12 mg IV rapidly). Adenosine is very expensive and short lived; propranolol (0.02 mg/kg slow intravenous boluses up to a total dose of 0.1 mg/kg). Propranolol has a long half-life after intravenous administration and also has significant β_2 blocking effects and is generally not recommended unless no other alternative is available.

Diet

- Mild to moderate sodium restriction if in CHF

Activity

- Restrict until arrhythmia has been controlled

Surgical Considerations

- Consider transvenous catheter ablation for patients with accessory pathways.

Appropriate Health Care

- Asymptomatic patients can be managed on an outpatient basis; patients with a sustained SVT or signs of congestive heart failure should be hospitalized until stable.

- SVT is a medical emergency in dogs that exhibit weakness and collapse; nonpharmacologic interventions that may break an SVT include vagal maneuvers, precordial thump, and electrical cardioversion.
- Vagal maneuvers are often unsuccessful but may be used initially because of their ease of administration and noninvasive nature.
- Delivering a precordial thump can successfully (>90 percent of the time) terminate an SVT in dogs, but this maneuver may break the rhythm for only a brief period. At other times the rhythm remains converted. To perform a precordial thump, the dog is placed on its right side and the left apex beat is located. This region is then “thumped” with a fist while recording the ECG.
- Emergency medical therapy is required in patients when a precordial thump is unsuccessful.

Nursing Care

- Treat CHF and correct any underlying electrolyte or acid-base disturbances.



COMMENTS

- Clinical signs may relate to the underlying cause.
- Dogs with slow SVT or infrequent paroxysmal SVT may exhibit no clinical signs.
- Dogs with fast SVT (heart rate usually >300 beats per minute) generally exhibit episodic weakness or syncope.

Client Education

- Owners should observe patients closely for signs of low cardiac output such as weakness and collapse.

Patient Monitoring

- Serial ECG or Holter monitoring

Possible Complications

- Syncope and CHF

Expected Course and Prognosis

- Most is controlled effectively with medication.

Synonyms

- Atrial tachycardia, junctional tachycardia

Abbreviations

- AV: atrioventricular
- CHF: congestive heart failure
- ECG: electrocardiogram
- IV: intravenously
- PO: by mouth
- SVT: supraventricular tachycardia

See Also

- Atrial fibrillation

Suggested Reading

- Atkins, CE, and Wright, KN. Supraventricular tachycardia associated with accessory pathways in dogs. In: Bonagura, JD, ed. *Current Veterinary Therapy XII*, pp. 807–810. Philadelphia: WB Saunders, 1995.
- Kittleson, MD. Diagnosis and treatment of arrhythmias (dysrhythmias). In: Kittleson, MD, and Kienle, RD, ed. *Small Animal Cardiovascular Medicine*, pp. 449–494. St. Louis: Mosby: 1998.
- Tilley, LP, Smith, FWK, Oyama, M, and Sleeper, M. *Manual of Canine and Feline Cardiology*. 4th ed. St Louis: Saunders/Elsevier, 2008.
- Wright, KN. Assessment and treatment of supraventricular tachyarrhythmias. In: Bonagura, JD, ed. *Kirk's Current Veterinary Therapy XIII*, pp. 726–730. Philadelphia: WB Saunders. 1999.

Author: Larry P. Tilley

Syncope



DEFINITION/OVERVIEW

- Temporary loss of consciousness and vascular tone associated with loss of postural tone, with spontaneous recovery



ETIOLOGY/PATHOPHYSIOLOGY

- Inadequate cerebral perfusion, delivery of oxygen, and metabolic substrates lead to loss of consciousness and motor tone.
- Impaired cerebral perfusion can result from changes in vasomotor tone, cerebral disease, and low cardiac output caused by structural heart disease or arrhythmias.

Risk Factors/Causes

- Heart disease
- Sick sinus syndrome
- Drug therapy: vasodilators (e.g., calcium channel blockers, ACE inhibitors, hydralazine, and nitrates), phenothiazines (e.g., acepromazine), anti-arrhythmics, and diuretics

Cardiac Causes

- Bradyarrhythmias: sinus bradycardia, sinus arrest, second-degree AV block, complete AV block, atrial standstill
- Tachyarrhythmias: ventricular tachycardia, supraventricular tachycardia, and atrial fibrillation
- Low cardiac output (nonarrhythmic): cardiomyopathy, AV valve endocardiosis, subaortic stenosis, pulmonic stenosis, heartworm disease, pulmonary embolism, cardiac tumor, or cardiac tamponade

Neurologic and Vasomotor Instability

- Vasovagal syncope: emotional stress and excitement may cause heightened sympathetic stimulation, leading to transient tachycardia and hypertension, which is followed by a compensatory rise in vagal tone, leading to excessive vasodilation without a compensatory rise in heart rate and cardiac output; bradycardia often occurs.

- Situational syncope refers to syncope associated with coughing, defecation, urination, and swallowing.
- Carotid sinus hyperactivity may cause hypotension and bradycardia, often the cause of syncope when one pulls on a dog's collar.

Miscellaneous Causes

- Drugs that affect blood pressure and regulation of autonomic tone
- Hypoglycemia, hypocalcemia, and hyponatremia (rare)
- Hyperviscosity syndromes (e.g., polycythemia and paraproteinemia) cause sludging of blood and impaired cerebral perfusion (rare).

Systems Affected

- Cardiovascular
- Nervous



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predilection

- Sick sinus syndrome: cocker spaniel, miniature schnauzer, pug, and dachshund
- Ventricular arrhythmias: boxer and German shepherd

Mean Age and Range

- More common in old animals

Historical Findings

- Acute collapse or weakness
- Suspected seizure



DIFFERENTIAL DIAGNOSIS

Differential Signs

- Must differentiate from other altered states of consciousness, including seizures and narcolepsy (a sleep disorder)
- Seizures are often associated with a prodromal and postictal period; syncope occurs without warning, and animal usually has rapid, spontaneous recovery. Unlike

syncope, seizure activity is usually associated with tonic-clonic muscle activity rather than flaccidity.

- Like syncope, narcolepsy occurs suddenly, results in muscle flaccidity, and resolves spontaneously. Unlike syncope, narcolepsy can last for minutes and can be terminated by loud noises or harsh external stimuli.
- Must differentiate from other causes of collapse such as musculoskeletal disease and neuromuscular disease (e.g., myasthenia gravis), which are not associated with loss of consciousness.

Differential Causes

- Syncope with excitement or stress suggests vasovagal syncope.
- Syncope with coughing, urination, or defecation suggests situational syncope.
- Syncope with exercise suggests low output states associated with arrhythmias or structural heart disease.
- A murmur supports heart disease but does not confirm cardiac cause for syncope.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Usually normal
- Hypoglycemia or electrolyte disturbance in some animals

Other Laboratory Tests

- If animal is hypoglycemic, measure insulin concentration on same blood sample.
- Calculate an amended insulin-to-glucose ratio to rule out insulinoma.
- If animal is hyponatremic or hyperkalemic, consider an ACTH stimulation test.
- If low cardiac output is suspected, rule out occult heartworm disease.

Imaging

Echocardiography

- May detect structural heart disease that could lower cardiac output

Diagnostic Procedures

- Have owner monitor heart rate during any syncopal episode.
- Electroencephalogram, computed tomography of the head, CSF tap if CNS origin suspected

Electrocardiographic Findings

- Postexercise ECG may reveal intermittent arrhythmia.

- Holter monitoring (24-hour ECG recording) or use of an ECG event (loop) recorder is useful for evaluating arrhythmic causes.
- Carotid sinus massage with ECG and blood pressure monitoring useful in evaluating carotid sensitivity



THERAPEUTICS

Drug(s) of Choice

Bradyarrhythmias

- Correct metabolic causes
- Anticholinergics (e.g., atropine, propantheline bromide, and hyoscyamine sulfate)
- Sympathomimetics (e.g., isoproterenol and bronchodilators)
- Pacemaker implantation in some patients

Tachyarrhythmias

- Atrial dysrhythmias: administer digoxin, β -blocker, or diltiazem
- Ventricular dysrhythmias: administer lidocaine, procainamide, mexiletine, sotalol, or β -blocker.

Low Cardiac Output

- Institute treatment to improve cardiac output, which varies according to specific cardiac disease.

Vasovagal

- Theophylline or aminophylline is sometimes helpful; mechanism of action in this setting is unclear
- β -blockers (e.g., atenolol, propranolol, and metoprolol) may indirectly prevent vagal stimulation by blocking the initial sympathetic response.
- Anticholinergics may blunt the vagal response.

Precautions/Interactions

- Drugs that lower blood pressure

Surgical Considerations

- Pacemaker implantation for sick sinus syndrome and advanced AV block and persistent atrial standstill

Appropriate Health Care

- Avoid or discontinue medications likely to precipitate syncope.
- Treat as outpatient unless important heart disease is evident.



COMMENTS

Client Education

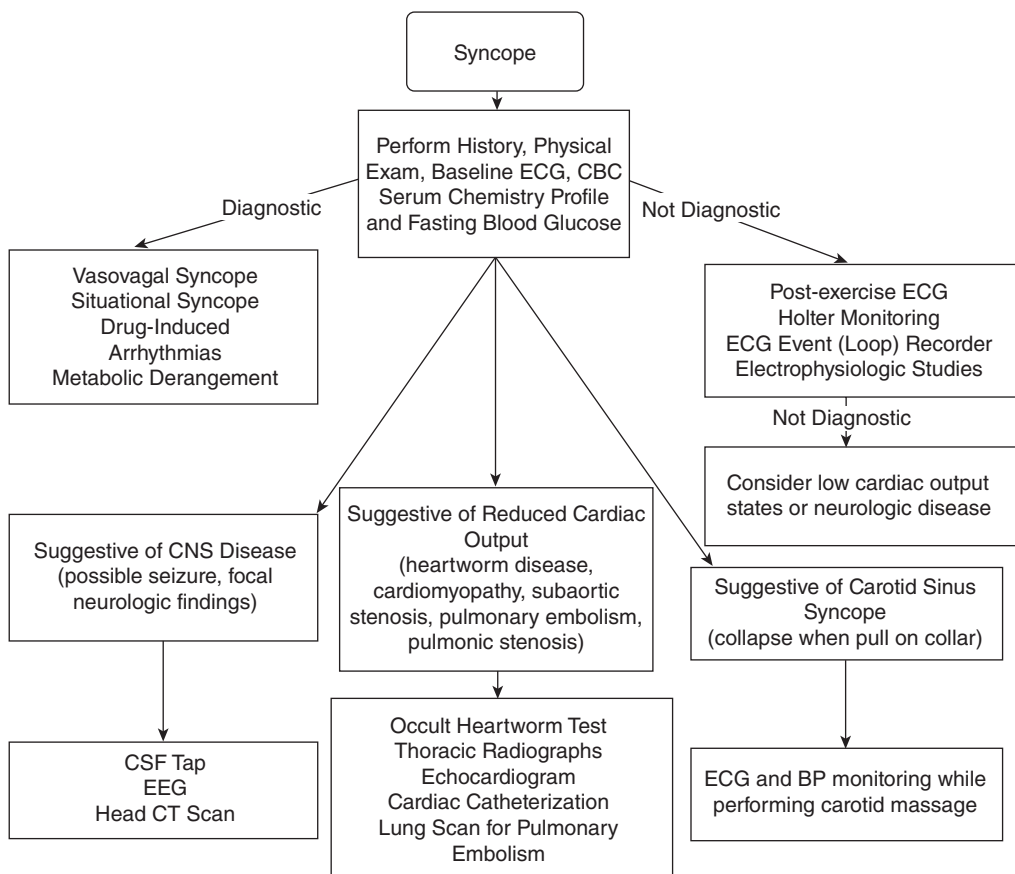
- Minimize stimuli that precipitate episodes.
- Low cardiac output: minimize activity.
- Vasovagal: minimize excitement and stress.
- Cough: remove collar.

Patient Monitoring

- ECG or Holter monitoring to assess efficacy of antiarrhythmic therapy (Figure 105.1)

Prevention/Avoidance

- See Client Education.
- Syncope



■ **Figure 105.1** Algorithm for syncope.

- Perform history, physical examination, baseline ECG, CBC serum chemistry and profile.

Possible Complications

- Death
- Trauma when collapse occurs

Expected Course and Prognosis

- Most noncardiac causes are not life-threatening; cardiac causes may be treated, but syncope in patients with cardiac disease may suggest higher mortality risk.

Synonyms

- Fainting

Abbreviations

- ACE: angiotensin-converting enzyme
- ACTH: adrenocorticotrophic hormone
- AV: atrioventricular
- CBC: complete blood count
- CNS: central nervous systems
- CSF: cerebrospinal fluid
- ECG: electrocardiogram

Suggested Reading

Calkins, H, and Zipes, DP. Hypotension and syncope. In: Zipes, DP, Libby, P, Bonow, RO, and Braunwald, E, eds. *Braunwald's Heart Disease: A Textbook of Cardiovascular Medicine*, 7th ed., pp. 909–920. Philadelphia: Elsevier Saunders, 2005.

Rush, JE. Syncope and episodic weakness. In: Fox, PR, Sisson, D, and Moise, NS, eds. *Textbook of Canine and Feline Cardiology*, pp. 446–455. Philadelphia: Saunders, 1999.

Internet Resource

- www.vetmed.wsu.edu/deptsVCGL/holter

Author: Francis W. K. Smith, Jr.

Tick Paralysis



DEFINITION/OVERVIEW

- Flaccid, lower motor neuron paralysis caused by salivary neurotoxins from certain species of female ticks



ETIOLOGY/PATHOPHYSIOLOGY

- The female tick of multiple species (*Dermacentor* and *Amblyomma* in the United States and *Ixodes* in Australia) injects salivary neurotoxins that interfere with the depolarization/acetylcholine release mechanism in the presynaptic nerve terminal.
- The Australian *Ixodes* tick neurotoxin depends strongly on temperature for activation and effect.
- Only one adult female *Dermacentor* or *Amblyomma* tick is sufficient to cause neurologic signs, but a large larval or nymphal *Ixodes* tick infestation can also induce signs.
- Signs occur 6 to 9 days after initial tick attachment.
- Not all infested animals develop signs of tick paralysis and not all adult female ticks produce the neurotoxin.

Systems Affected

- Nervous/Neuromuscular—peripheral nervous system and the neuromuscular junction most affected by the neurotoxin; cranial nerves can become involved, including the vagus, facial, and trigeminal nerves; sympathetic nervous system can also be affected.
- Respiratory—may see paralysis of the intercostal muscles and diaphragm; caudal brainstem respiratory centers may be affected especially with *Ixodes* tick infestation.



SIGNALMENT/HISTORY

- In Australia, both dogs and cats are equally affected by the *Ixodes* neurotoxin.
- In North America, however, cats appear to be resistant to the *Dermacentor* and *Amblyomma* neurotoxin.

Risk Factors/Causes

- The incidence of tick paralysis is somewhat seasonal, with a greater incidence in the summer months.
- In warmer areas (southern United States and northern Australia), tick paralysis is a year-round problem.
- The overall incidence of tick paralysis is relatively low in North America with a higher incidence of tick paralysis in Australia.
- In the United States, *D. variabilis* has a wide distribution over the eastern two-thirds of the country and in California and Oregon.
- *D. andersoni*, however, is found only from the Cascades to the Rocky Mountains.
- *A. americanum* has a southern U.S. distribution from Texas and Missouri to the Atlantic Coast.
- *A. maculatum* has even a narrower range, preferring the high temperature and humidity of the Atlantic and Gulf of Mexico seaboards.
- In Australia, *I. holocyclus* is limited to the coastal areas of the east, especially in areas associated with bush and scrub.

Historical Findings

- The classic history would be that the patient walked in a wooded area approximately 1 week prior to the onset of signs.
- Onset of neurological dysfunction is gradual, starting with stumbling and weakness in the pelvic limbs, followed by a rapid progression to tetraparesis with possible cranial nerve and autonomic signs.

Neurologic Examination Findings

- In non-*Ixodes* ticks, once neurologic signs appear, there is rapid ascending lower motor neuron paresis to paralysis.
- Many dogs will become recumbent in 1 to 3 days, with hyporeflexia/areflexia and hypotonia/atonie.
- Occasionally, signs are much milder, with the dog still able to ambulate.
- Pain sensation is preserved.
- Cranial nerve dysfunction is usually not a prominent feature, with the most common signs being facial weakness and dysphonia.
- Respiratory paralysis is very rare in the United States.
- Urination and defecation are usually normal.
- With intoxication by the *Ixodes* tick, the neurologic signs are much more severe and rapidly progressive.
- The ascending motor paresis can progress to paralysis within a few hours, along with sialosis, megaesophagus, and vomiting or regurgitation.
- There is sympathetic nervous system dysfunction, manifesting as mydriatic, poorly responsive pupils, hypertension, tachyarrhythmias, high pulmonary capillary hydrostatic pressure, and pulmonary edema.

- There is additional involvement of the caudal medullary respiratory centers, which add to the peripheral pulmonary changes, resulting in a progressive fall in respiratory rate without a change in tidal volume, leading to hypoxia, hypercapnia, and respiratory acidosis.
- Respiratory muscle paralysis is much more prevalent, with both dogs and cats progressing to respiratory distress, cyanosis, and respiratory paralysis within 1 to 2 days if not treated.



DIFFERENTIAL DIAGNOSIS

- Botulism
- Acute polyneuropathy
- Coonhound paralysis (acute canine polyradiculoneuritis)
- Distal denervating disease
- Generalized (diffuse) or multifocal myelopathy



DIAGNOSTICS

- Regular blood work will be normal in animals with tick paralysis.
- In severely affected patients, especially with the *Ixodes* tick, arterial blood gases will reveal a low PaO₂, a high PaCO₂, and a low pH.
- Thoracic radiographs will be normal in dogs affected by ticks in North America, but often will reveal a megaesophagus in patients affected by the *Ixodes* neurotoxin.
- Electrodiagnostic evaluation will reveal normal insertion activity and an absence of spontaneous myofiber activity (no fibrillations and positive sharp waves) on electromyography (normal), but motor nerve conduction studies will reveal a significant decrease or absence of compound muscle potential amplitudes.



THERAPEUTICS

- If tick paralysis is suspected, the patient should be hospitalized until either a tick is found and removed or appropriate treatment to kill a hidden tick is performed.
- Thoroughly search for a tick in all body areas including the trunk and limbs, ear canals, mouth, rectum, vagina, prepuce, and in between the digits and foot pads.
- If a tick is found, it should be immediately removed.

Drug(s) of Choice

- If the tick cannot be found, use a topical insecticidal product such as Frontline or dip the patient in an insecticidal bath.

- With tick paralysis in North America, this is often the only specific treatment needed.
- With *I. holocyclus*, circulating toxin must be neutralized via hyperimmune serum (0.5–1 mg/kg IV), depending on the severity of clinical signs.
- If the clinical signs are severe and involve the sympathetic nervous system, phenoxybenzamine, an α -adrenergic antagonist (1 mg/kg IV diluted in saline and given slowly over 20 minutes), appears to be beneficial.
- Acepromazine (0.5–1 mg/kg IV) can be used as an alternative treatment because it has an α -adrenergic blocking effect.

Precautions/Interactions

- Inpatient supportive care is essential until the patient begins to show signs of recovery.
- If the patient demonstrates hypoxia or hypoventilation, an oxygen cage should be used.
- Assisted ventilation may occasionally be necessary in severe cases, especially with *Ixodes* neurotoxicity.
- Intravenous fluid therapy is generally not required unless recovery is prolonged, the neurological dysfunction is severe, or there is evidence of megaesophagus.
- Administer intravenous fluids at a very slow rate to avoid further complications of pulmonary congestion in *Ixodes* neurotoxicity.
- Keep the patient in a quiet environment until recovery.
- The patient with *Ixodes* neurotoxicity should be housed in a cool, air-conditioned area because the neurotoxin is temperature sensitive. Avoid activity to prevent any increase in body temperature.
- Drugs that interfere with neuromuscular transmission are contraindicated. These include tetracycline, aminoglycosides, and procaine penicillin.
- Atropine is contraindicated in the advanced stages of *Ixodes* neurointoxication or with marked bradycardia.

Diet

- Withhold food and water if the patient has dysphagia or vomiting/regurgitation.



COMMENTS

Client Education

- For non-*Ixodes* ticks, inform the client that good nursing care is essential, although the patient's recovery is rapid after removal of the tick.
- For the *Ixodes* tick, warn the client that signs often worsen despite tick removal. Therefore, more aggressive treatment to neutralize the toxin must be undertaken.

Patient Monitoring

- For non-*Ixodes* ticks, you should reassess neurologic status after tick removal at least on a daily basis. Rapid improvement in muscle strength should occur within 24 to 48 hours.
- For the *Ixodes* tick, you need to monitor neurologic status and respiratory/cardiovascular functions continuously and intensively even after tick removal because of the residual effect of the neurotoxin.

Prevention/Avoidance

- Vigilantly check for ticks after exposure (at least every 2–3 days). Remember that signs do not occur for 4 to 6 days after tick attachment.
- Advise the owner to regularly use a topical insecticide or give weekly insecticidal baths.
- Short-term acquired immunity develops after exposure to the *Ixodes* neurotoxin.

Expected Course and Prognosis

- For non-*Ixodes* ticks, prognosis is good to excellent if ticks are removed appropriately, with recovery occurring in 1 to 3 days.
- Prognosis is often guarded for the *Ixodes* tick, with a prolonged recovery. If left untreated, death will usually occur in 1 to 2 days.

Abbreviations

- IV: intravenously
- PaO₂: partial pressure of oxygen in blood
- PaCO₂: partial pressure of carbon dioxide in blood
- pH: acid-base

Suggested Reading

- Atwell, RB, Campbell, FE, and Evans, EA. Prospective survey of tick paralysis in dogs. *Aust Vet J* 2001;79:412–418.
- Lorenz, MD, and Kornegay, JN. *Handbook of Veterinary Neurology*, 4th ed., 191–192. St. Louis: Saunders/Elsevier, 2004.
- Malik, R, and Farrow, BRH. Tick paralysis in North America and Australia. *Vet Clin North Am* 1991;21:157–171.

Author: Paul A. Cuddon

Tracheal Collapse



DEFINITION/OVERVIEW

- Tracheal collapse generally refers to a condition of excessive collapsibility of the trachea.
- A collapsing trachea has a wide, flaccid dorsal tracheal membrane that is redundant and sags into the lumen; further, weakened cartilaginous rings may form a shallow arch impinging on the lumen of the trachea.



ETIOLOGY/PATHOPHYSIOLOGY

- Tracheal collapse has been associated with other conditions such as tracheal trauma, intra- and extraluminal masses, and tracheal hypoplasia.
- The typical syndrome of tracheal collapse where the trachea is excessively collapsible has an unclear etiology. Several theories have been proposed including genetic, nutritional, neurological, and inflammatory causes.

Systems Affected

- Respiratory—Severe tracheal collapse can lead to respiratory distress and hypoxemia. Concurrent bronchitis or pneumonia may be present.
- Cardiovascular—Chronic cough and airway disease can be an underlying cause of pulmonary hypertension and right-sided heart failure.



SIGNALMENT/HISTORY

- Toy and miniature breeds are most commonly affected. Frequently affected breeds include toy poodle, Yorkshire terrier, Pomeranian, Maltese, pug, and Chihuahua.
- Tracheal collapse is occasionally reported in large breeds, and rarely reported in cats.
- Most dogs with tracheal collapse are middle-aged, and the reported average age of onset is 6.6 to 8 years of age. There is a biphasic age distribution with a subpopulation showing signs of tracheal collapse during puppyhood.

Historical Findings

- Cough is the classic historical finding, and it may have been present for several weeks prior to the client seeking veterinary attention. The cough is often dry, hacking, and nonproductive; although a terminal retch or a moist cough may be present. The cough is most often described as a “goose-honking” cough. Initially the cough may have been mild but often progresses and there are bouts of severe, paroxysmal coughing episodes.
- Coughing bouts may be precipitated by excitement or tracheal irritation such as pulling on a neck leash. Severe cases can suffer respiratory distress at rest, cyanosis, and collapse. Exercise intolerance may be reported, although this may not be reported in dogs with a sedentary lifestyle.
- Up to two-thirds of patients are reported as obese.
- Gagging after eating or drinking is reported in 30 percent of dogs with tracheal collapse.



CLINICAL FEATURES

- Physical examination findings will vary from an apparently normal dog to findings of severe, paroxysmal cough with possible cyanosis or collapse.
- A harsh cough can be easily induced with gentle tracheal palpation. Thoracic auscultation will reveal harsh wheezing sounds in patients with concurrent chronic bronchitis.
- Cardiac auscultation is typically normal, although a split S2 from delayed closure of the tricuspid valve may be present in patients with pulmonary hypertension.
- Incidental chronic mitral valve disease and a loud systolic mitral murmur may be present falsely raising the suspicion of congestive heart failure.



DIFFERENTIAL DIAGNOSIS

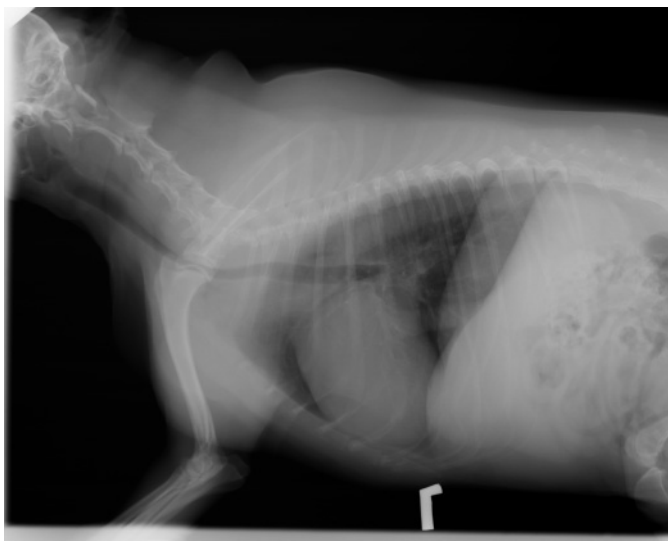
- Chronic bronchitis
- Infectious tracheobronchitis
- Tracheobronchial foreign body
- Brachycephalic airway syndrome
- Congestive heart failure
- Pneumonia



DIAGNOSTICS

Radiography

- Lateral radiographs of the cervical and thoracic regions are commonly obtained in diagnosing tracheal collapse; dorsoventral flattening of the trachea may be observed. (Figure 107.1)



■ **Figure 107.1** Lateral thoracic radiograph of a dog with tracheal collapse at the thoracic inlet. Also present is a redundant dorsal trachealis membrane.

- Reported sensitivity for routine lateral radiographs is reported between 60 and 84 percent; false-negative findings on routine films occur with substantial frequency.
- False-positives may also occur with superimposition of overlying structure such as the esophagus or *longus colli* or *longus capitis* muscles.
- Because of the dynamic nature of tracheal collapse, both inspiratory and expiratory views should be obtained as intrathoracic tracheal collapse will be evident on expiration and cervical tracheal collapse will be evident on inspiration.
- Alternatively fluoroscopy has the advantage of continuous documentation through all phases of respiration and is preferred by many clinicians.
- Routine thoracic and cervical radiographs are indicated in patients with cough or respiratory distress; patients should be medically stabilized prior to obtaining stressful diagnostic images.

Tracheobronchoscopy

- Advances in fiberoptic and videobronchoscopy have increased the availability of this technique. Direct tracheal imaging allows visualization of dynamic tracheal lesions, intraluminal masses, and opportunity to grade the extent of tracheal collapse (i.e., cervical, thoracic, both), and exclude false-positive radiographic findings.
- Tracheal collapse grading system:
 - Grade I: slightly pendulous trachealis muscle with up to 25 percent luminal loss
 - Grade II: the trachealis muscle is more pendulous and the lumen is reduced by up to 50 percent.
 - Grade III: severe flattening of the cartilaginous rings; the dorsal tracheal membrane is nearly in contact with the opposing wall and there is up to 75 percent luminal loss.

- Grade IV: total tracheal collapse; dorsal tracheal membrane lies on the ventral floor, the lumen is obliterated.
- Tracheoscopy is typically performed with concurrent pharyngoscopy, laryngoscopy and bronchoscopy as other forms of airway disease may exist concurrently with tracheal collapse.

Cytology and Bacteriology

- Obtaining airway wash samples for cytology and bacteriology is often advocated; however 36 percent of clinically normal dogs have positive bacterial cultures from lower tracheal swabs. Common bacteria isolated include alpha-hemolytic streptococci, *Pasteurella multocida*, *Klebsiella pneumoniae*, and coagulase positive staphylococci. Upper airway culture should be carefully interpreted with cytology to avoid inappropriate antimicrobial use.



THERAPEUTICS

- The objectives of therapy include resolving respiratory distress, resolution of severe cough, and return to adequate function.

Drug(s) of Choice

- Supplemental oxygen should be provided to patients in distress.
- Antitussives help break the cycle of cough-induced airway irritation that leads to more cough.
 - Butorphanol tartrate: 0.2 to 0.4 mg/kg SQ, IM, or IV every 4 to 6 hours
 - Hydrocodone: 0.22 mg/kg PO every 6 to 12 hours
- Sedation of hyperactive animals can help break the cough-induced cycle.
 - Butorphanol has sedative properties.
 - Acepromazine: 0.05 to 0.1 mg/kg IM or IV every 8 to 12 hours
 - Diazepam: 0.1 to 0.6 mg/kg IV
- Bronchodilators may be helpful in cases where concurrent small airway disease is present.
 - Terbutaline: 0.01 mg/kg IM, or 1.25 to 2.5 mg/dog PO every 12 hours
 - Theophylline: 10 mg/kg PO every 12 hours
- Glucocorticoid treatment is controversial and may be advantageous in patients with concurrent small airway disease.
 - Anti-inflammatory prednisone: 0.25 to 0.5 mg/kg every 12 hours
- Antibiotic use should be restricted to cases with documented concurrent infection.

Diet

- Obese animals should be placed on strict diet and a strict follow up plan to assess weight loss.

Activity

- Excessive activity and excitement can precipitate a paroxysmal coughing bout and routine tranquilization may be needed especially during times of anticipated increased pet activity.

Surgical Considerations

- Surgical options that are commonly utilized include extraluminal ring prostheses and intraluminal stent placement.
- Procedures are intricate and should be performed by experienced specialists.
- Because the procedures carry significant morbidity and mortality, many authors reserve such invasive procedures for only those patients who have failed medical management.



COMMENTS

Client Education

- The majority of patients are managed medically.

Patient Monitoring

- Cough frequency will be mainstay of patient monitoring.
- Patient return to activity

Prevention/Avoidance

- Avoid neck leashes and other cervical irritants.
- Strive for ideal body condition score.

Possible Complications

- Complications of medical management are minimal. Prolonged prednisone usage may contribute to weight gain due to polyphagia.
- Complications of extraluminal tracheal prostheses include laryngeal paralysis, necrotizing tracheitis from blood flow disruption.
- Complications from intraluminal tracheal stent placement include stent migration, stent fracture, pneumonia, and tracheal granulation tissue.

Expected Course and Prognosis

- For severe cases the prognosis fair to guarded.

Synonyms

- Collapsing trachea
- Collapsed trachea

Abbreviations

- IM: intramuscularly
- IV: intravenously
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

Johnson, L. Tracheal collapse. *Vet Clin North Am Small An Pract* 2000;30:1253–1266.

Mason, RA, and Johnson, LR. Tracheal collapse. In: King, LG, ed. *Textbook of Respiratory Disease in Dogs and Cats*, pp. 346–355. St. Louis: Elsevier, 2004.

White, RAS, and Williams, JM. Tracheal collapse in the dog—Is there really a role for surgery? A survey of 100 cases. *J Small Anim Pract* 1994;11:191–196.

Author: Jonathan F. Bach

Traumatic Myocarditis



DEFINITION/OVERVIEW

- Traumatic myocarditis is a term used by veterinarians to describe a presumed myocardial injury secondary to blunt nonpenetrating thoracic trauma that most commonly results in ventricular dysrhythmias in the dog.



ETIOLOGY/PATHOPHYSIOLOGY

- The most common mechanism of myocardial contusion in the dog is secondary to lateral chest compression that subjects the myocardium to compressive and concussive forces. Additionally, it has been proposed that distortion of the thoracic cage results in a rise in intrathoracic and intracardiac pressures, causing shearing stresses within the myocardium powerful enough to result in myocardial injury. Conditions other than direct injury to the heart such as metabolic acidosis, hypoxia, electrolyte imbalance, intracranial injuries, and catecholamine release may also cause dysrhythmias in traumatized dogs.

Systems Affected

- Cardiovascular—dysrhythmias, hypotension, weak pulses, or tachycardia
- Musculoskeletal—weakness, rib fractures, or trauma severe enough to result in limb and pelvic fractures frequently causes myocardial contusion
- Nervous—decreased responsiveness, disorientation, or weakness
- Renal/Urologic—decreased urine output
- Respiratory—hypoxia or pulmonary contusion
- Skin—bruising over thoracic cage could be seen



SIGNALMENT/HISTORY

Risk Factors/Causes

- These are no known medical conditions, medications, or environmental factors that predispose the dog or cat to developing this condition.

Historical Findings

- Trauma is the only presenting complaint that is associated with traumatic myocarditis. Most commonly automobile induced injury is associated with this condition but other injuries such as animal attacks (i.e., bite, kicks) and falls from height can also cause myocardial injuries.



CLINICAL FEATURES

Dogs

- The diagnostic gold standard in the identification of cardiac injury remains the gross or histologic examination of the heart. Because visualization or myocardial biopsy is uncommon, a high index of suspicion for and understanding of myocardial injury are essential in making a diagnosis. Traumatic myocarditis should be suspected in traumatized dogs with the following injuries: (1) fractures of extremities, the spine or pelvis, (2) external evidence of thoracic trauma, (3) radiographic evidence of chest trauma such as pulmonary contusions, pneumothorax, hemothorax, diaphragmatic hernia, and rib/scapular fractures, and (4) neurologic injury. Cardiac dysrhythmias are frequently delayed in onset up to 48 hours after the inciting event.

Cats

- This condition has not traditionally been reported in cats but remains possible, and the same features reported in dogs could easily be applied to cats once underlying cardiac disease was ruled out.



DIFFERENTIAL DIAGNOSIS

Dogs

Dysrhythmias associated with trauma may also be caused by:

- Underlying heart disease
- Metabolic acidosis
- Hypoxia
- Electrolyte imbalance
- Intracranial injuries
- Pain (catecholamine release).



DIAGNOSTICS

- Blood work
 - CBC, biochemistry panel, urinalysis, and arterial or venous blood gas
 - Radiographs

- Thoracic—pulmonary contusions, pneumothorax, hemothorax, or rib fracture
 - Abdominal—evidence of effusion (i.e., blood, urine), free abdominal gas
 - Appendicular—fractures
- Echocardiogram
 - Abnormal findings may include:
 - Increased end-diastolic wall thickness
 - Impaired contractility, indicated by wall motion abnormalities and decreased fractional shortening
 - Increased echogenicity
 - Localized areas of echolucency consistent with intramural hematomas.
- ECG—ventricular dysrhythmias most common, often delayed in onset up to 48 hours
 - Intermittent
 - Continuous
 - Holter monitoring
- Serum myocardial isoenzyme/proteins
- CPK-MB
- Cardiac troponins (T and I)

Pathological Findings

- Pathologic findings in the traumatized heart have been characterized by localized edema, ecchymosis, and intramycardial hematoma formation. These injuries are often transmural with the epicardial surface being more severely affected.
- Dysrhythmias and conduction defects are the most common physiologic consequences to myocardial injuries.
- The most common dysrhythmias encountered secondary to canine myocardial injuries include premature ventricular contractions, ventricular tachycardia, and non-specific S-T segment elevation or depression.
- Although less frequent than ventricular dysrhythmias, other dysrhythmias reported in dogs with chest trauma include atrial fibrillation, sinus arrest with ventricular, or junctional escape complexes and second- and third-degree AV block.



THERAPEUTICS

- Treatment is typically aimed at suppressing potentially life-threatening dysrhythmias such as multiform premature ventricular complexes, ventricular tachycardia, and the R-on-T phenomenon. Dysrhythmias that result in hypotension, weakness, pale mucous membranes, delayed capillary refill time, collapse, or syncope in patients that have received adequate fluids, electrolytes, oxygen, and pain control should also be addressed. The therapeutic goal of these recommendations is not necessarily total alleviation of the dysrhythmia; adequate therapy may be reduction of the heart rate (<140 beats per minute) or the return of hemodynamic stability.

Drug(s) of Choice

- Lidocaine: 2 mg/kg intravenous bolus. Lidocaine boluses may be repeated as needed every 10 to 20 minutes until a cumulative dose of 8 mg/kg is given. If the therapeutic response is favorable to intravenous bolus therapy, an intravenous CRI of 40 to 80 μ g/kg per minute should be initiated to maintain a normal rhythm. In many cases, additional boluses may be required to suppress the arrhythmia while steady state blood levels of lidocaine are achieved by the CRI.
- When lidocaine fails to resolve ventricular ectopy, procainamide may be administered IV or IM (6–15 mg/kg every 4–6 hours). Procainamide may also be administered as a CRI (10–40 μ g/kg per minute) or given orally (sustained release formulation 20 mg/kg three times daily). Good success is noted in transitioning to mexiletine (4–8 mg/kg PO three times daily) as an oral anti-arrhythmic for animals being discharged that require continued suppression of arrhythmias.
- The addition of a β -blocker should be considered for the treatment of ventricular ectopy that remains unresponsive to class I anti-arrhythmics in traumatized dogs. Use of β -blockers should be reserved for patients that have been appropriately treated for shock and are not receiving positive inotropic medications.
- In some instances, ventricular ectopy will not be suppressed with antiarrhythmic drugs alone. Careful monitoring of the patient's electrolyte and acid-base status is necessary because acidosis, hypokalemia, and hypomagnesemia can be present and promote continued ventricular tachycardia. Judicious use of potassium supplementation (dose according to degree of hypokalemia) and magnesium chloride (0.75 mEq/kg/day IV CRI) should be considered when acid-base and electrolyte derangements are also present.

Precautions/Interactions

- High doses of lidocaine can result in seizures; cats are very sensitive to the adverse side effects of lidocaine.
- Hypotension and AV conduction block are serious potential side effects of procainamide administration.
- β -blockers can result in serious potential side effects such as AV block, hypotension, bronchoconstriction, and decreased cardiac contractility.
- Oral anti-arrhythmics can cause gastrointestinal upset such as anorexia and vomiting.
- Use care to avoid administration of more than 0.5 mEq/kg per hour potassium supplementation.
- Oversupplementation with magnesium chloride can cause muscle fasciculation, tremors, and AV block.

Activity

- Activity restriction will depend on primary injuries, but the author recommends a minimum of 2 weeks of exercise restriction to allow cardiopulmonary injuries to resolve.

Surgical Considerations

- If a patient with a myocardial injury must undergo anesthesia, drugs should be selected that are least likely to induce arrhythmias, such as acepromazine, butorphanol, isoflurane, and glycopyrrolate. Halothane, atropine sulfate, and the thiobarbiturates would be poor choices as they tend to exacerbate dysrhythmias and sensitize the heart to catecholamine induced dysrhythmias.



COMMENTS

- Onset of dysrhythmias can be delayed for up to 24 hours. Treatment is only required in cases with potentially fatal arrhythmias (V-tach, Ron T) and animals with clinical evidence or hypotension, weak, poor pulses or pulse deficits, or decreased cardiac output associated with a dysrhythmia. Dysrhythmias associated with trauma should only be addressed after the other physiologic consequences associated with sustained injuries are appropriately treated (i.e., fluids, oxygen, pain). Most dysrhythmias associated with myocardial trauma do not require treatment and resolve in 3 to 10 days.

Client Education

- Monitor for weakness, respiratory distress, pale mucous membranes, and irregular pulses.

Patient Monitoring

- It is recommended that intermittent ECG monitoring continue up to 1 week after discharge. Prior to re-examination, antiarrhythmic medications should be discontinued for a minimum of 24 hours. Holter monitoring, if available, would be the most sensitive way to detect complete resolution of arrhythmias after discontinuing antiarrhythmic medications.

Possible Complications

- Some dysrhythmias could be fatal if not suppressed. Myocardial dysfunction secondary to trauma could result in congestive failure. Persistent dysrhythmias and myocardial dysfunction could occur and require lifelong therapy.

Expected Course and Prognosis

- Prognosis is very good; most dysrhythmias resolve within 1 to 2 weeks, complications are rare.

Synonyms

- Blunt myocardial injury, myocardial cell injury, myocardial contusion, and cardiac contusion

Abbreviations

- AV: atrioventricular
- CPK-MB: creatine phosphokinase myocardial band
- CRI: constant rate infusion
- ECG: electrocardiogram
- IM: intramuscularly
- IV: intravenously
- PO: by mouth

Suggested Reading

- Abbott, JA. Traumatic myocarditis. In: Bonagura, JD, ed. *Current Veterinary Therapy XII*, pp. 846–850. Philadelphia: WB Saunders, 1995.
- Reiss, AJ, McKiernan, BC, Wingfield, WE, et al. Myocardial injury secondary to blunt thoracic trauma in dogs: Incidence and pathophysiology. *Comp Cont Ed Prac Vet* 2002;24(12):934–941.
- Reiss, AJ, McKiernan, BC, Wingfield, WE, et al. Myocardial injury secondary to blunt thoracic trauma in dogs: Diagnosis and treatment. *Comp Cont Ed Prac Vet* 2002;24(12):944–951.
- Schober, KE, Kirbach, B, and Oechtering, G. Noninvasive assessment of myocardial cell injury in dogs with suspected cardiac contusion. *J Vet Cardiol* 1999;1(2):17–25.
- Snyder, SS, Cooke, KL, Murphy, ST, et al. Electrocardiographic findings in dogs with motor vehicle-related trauma. *J Am Anim Hosp Assoc* 2001;37(1):55–63.

Author: Adam J. Reiss

Urethral Prolapse



DEFINITION/OVERVIEW

- Extrusion of the urethral mucosa through the urethral orifice



ETIOLOGY/PATHOPHYSIOLOGY

- Unknown; may occur after sexual excitement, concurrent with urethral infections or may be the result of increased intra-abdominal pressure in brachycephalic breeds
- Genetic or congenital abnormalities may be involved.

Systems Affected

- Urologic—hematuria, urinary incontinence, or pollakiuria
- Reproductive—intermittent erection



SIGNALMENT/HISTORY

- Male dogs: English bulldogs and other brachycephalic breeds, Boston terriers, Yorkshire terriers; rare in other breeds
- Young dogs: 9 to 18 months old
- Not reported in cats

Historical Findings

- Penile hemorrhage
- Urinary signs (i.e., pollakiuria, stranguria, or hematuria)
- Sexual excitement
- Licking of the penis
- Mass on the tip of penis



CLINICAL FEATURES

- Red pea-shaped structure at the end of the penis (Figure 109.1)
- Urethral/penile bleeding



■ **Figure 109.1** Prolapsed urethra in a bulldog. Note the irritated appearance of the mucosa extruding from the tip of the dog's penis.



DIFFERENTIAL DIAGNOSIS

- Trauma
- Urinary tract infection
- Urethritis
- Cystic/urethral uroliths
- Penile neoplasia
- Prostate disease
- Testicular disease
- Os penis fractures
- Anatomic abnormalities; persistent penile frenulum or hypospadias



DIAGNOSTICS

- CBC and serum biochemistry: anemia (regenerative) if significant blood loss
- Urinalysis: hematuria in a voided sample
- PT, PTT, BMBT, and platelets to rule out coagulopathy
- Urine culture and sensitivity
- Abdominal radiographs: rule out radiodense uroliths, urethral obstruction, evaluate the prostate, and evaluate the os penis for fractures

- Abdominal ultrasound: rule out radiolucent uroliths, bladder neoplasia, and prostatic disease
- Cystography: double contrast study to rule out uroliths, and other urethral, prostatic, and bladder diseases



THERAPEUTICS

The objective is reduction of the prolapsed urethral mucosa to restore urinary function, not necessarily reproductive function.

- Medical management: consider if asymptomatic and minimal episodic bleeding, seldom curative
- An e-collar is necessary to prevent self-trauma.

Drug(s) of Choice

- NSAIDs: Carprofen 2.2mg/kg PO every 12 hours
- Opioids: Hydromorphone 0.05 to 0.2mg/kg IV, IM, or SQ every 4 to 6 hours; Tramadol 1 to 4mg/kg PO every 8 to 12 hours
- Antibiotics appropriate to urine and prostatic culture and susceptibility

Precautions/Interactions

- Standard anesthetic precautions with brachycephalic breeds

Activity

- Decreased activity; sedation may be necessary
- Prevent contact with female dogs during recovery period.

Surgical Considerations

- Consider if extensive prolapse, ulceration, necrosis, or severe bleeding; recommended therapy in most cases
 - Surgical options: purse string, surgical excision, and urethropexy
 - Castration: controversial for the treatment of sexual excitement but is often recommended to help prevent recurrence
- An E-collar is necessary.
- Treat any underlying urinary or reproductive disease.



COMMENTS

Client Education

- Warn owners that recurrence is possible even with surgical correction.

Patient Monitoring

- PCV
- Ability to urinate
- Urethral mucosa—progressing prolapse and trauma

Prevention/Avoidance

- Avoid female dogs, if associated with excitement and erection
- Correction of brachycephalic airway syndrome may decrease intra-abdominal pressure.

Possible Complications

- Anemia, self-trauma, surgical dehiscence, infection, and recurrence

Expected Course and Prognosis

- Prolapse, bleeding, and trauma may progress until surgical correction is necessary.
- Prognosis: good, however, recurrence is possible

Abbreviations

- BMBT: buccal mucosal bleeding time
- CBC: complete blood count
- IM: intramuscularly
- IV: intravenously
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PCV: packed cell volume
- PO: by mouth
- PT: prothrombin time
- PTT: partial thromboplastin time
- SQ: subcutaneously

Suggested Reading

Osborne, CA, and Sanderson, SL. Medical management of urethral prolapse in male dogs. In: Bonagura, JD, ed. *Kirks Current Veterinary Therapy XII Small Animal Practice*, pp. 1027–1029. Philadelphia: W.B. Saunders, 1995.

Author: Stacy D. Meola

Acknowledgment to original authors in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Sherry L Sanderson and Carl A Osborne

Vaginal Hyperplasia/ Prolapse



DEFINITION/OVERVIEW

- Protrusion of spherical or donut-shaped mass from vulva during proestrus or estrus
- Type I: slight eversion of the vaginal floor but no protrusion through the vulva
- Type II: vaginal tissue prolapses through the vulvar opening (tongue-shaped mass)
- Type III: donut-shaped eversion of the entire vaginal wall, including the urethral orifice, which can be seen ventrally on the prolapsed tissue (Figure 110.1)
- Exaggerated response of vaginal mucosa to estrogen, some affected animals have follicular cysts
- Despite the name, the change seen histopathologically is consistent with edema rather than hyperplasia or hypertrophy.
- Severe prolapse: may occlude the urethra and prevent normal urination



■ **Figure 110.1** Vaginal hyperplasia in a 3-year-old pug.



ETIOLOGY/PATHOPHYSIOLOGY

- Exaggerated response of vaginal lining to presence of estrogen level normally present during proestrus/estrus
- Some bitches may have follicular cysts, but this is not common or necessary to produce vaginal hyperplasia.
- Exogenous exposure to estrogens, such as human skin to which hormone replacement therapy cream has been applied, may also result in vaginal hyperplasia
- A few bitches have recurrence near the end of diestrus, in association with a rise in estrogen at that time

Systems Affected

- Reproductive: protrusion of edematous vaginal tissue through vulva
- Urologic: Stage III can cause urethral occlusion and obstructive renal failure.



SIGNALMENT/HISTORY

- Usually seen in younger bitches, typically on their first heat cycle
- A number of breeds have been reported affected; due to the increased incidence in some breeds, a genetic cause is postulated.
- Increased incidence has been reported in boxer, mastiff, bull mastiff, bulldog, American pit bull terrier and related breeds, and Labrador retriever.
- Also reported in Saint Bernards, German shepherd dogs, walker hounds, Chesapeake Bay retrievers, springer spaniels, Weimeraners, Airedale terriers, and mixed breeds

Historical Findings

- Currently in proestrus or estrus
- Occasionally in late gestation or diestrus
- Protrusion of tissue through the vulva
- Failure to allow mating
- Difficulty urinating
- Excessive licking of vulva
- Prior occurrence



CLINICAL FEATURES

- Protrusion of round, tongue-shaped, or donut-shaped tissue mass from the vulva
- Vaginal examination: locate lumen and urethral orifice; types I and II: lumen is dorsal to the prolapse; type III: lumen is central to the prolapse; urethral orifice is ventral to the prolapse.
- Prolapse with all three types
- Tissue may be dry or necrotic.



DIFFERENTIAL DIAGNOSIS

- Vaginal polyp—differentiated by vaginal examination
- Vaginal neoplasia—transmissible venereal tumor and leiomyoma; differentiated by signalment, stage of cycle, and vaginal examination
- Clitoral hypertrophy; differentiated by careful physical examination



DIAGNOSTICS

- Vaginal cytology to determine stage of cycle and presence of estrogen stimulation
- Biopsy in older bitch if needed to differentiate from neoplasia
- Sedation and vaginoscopy if necessary to differentiate from other masses

Pathological Findings

- Careful vaginal examination differentiates from other causes of vaginal masses.
- Histopathology shows dramatic edema of vaginal lining.



THERAPEUTICS

- Outpatient; unless urethral obstruction
- Breeding—possible by artificial insemination (discuss heritability)
- Prolapsed tissue—keep clean and lubricated with sterile water-soluble lubricant
- Minimize tissue trauma
- Instruct client to monitor patient's ability to urinate
- If urethral obstruction present, place indwelling urinary catheter (Figure 110.2)
- Regression—usually begins in late estrus; should be resolved during early diestrus
- Recurrence rate—66 to 100 percent at next estrous cycle
- Ovariohysterectomy—prevents recurrence; may hasten resolution if performed early in proestrus
- Severe condition—requires surgical reduction or resection; if possible, perform when the mass is beginning to regress; identify and catheterize urethra, 25 percent recurrence at next cycle after surgery

Drug(s) of Choice

- GnRH (2.2 µg/kg IM) or hCG (1,000 IU IM), if breeding not planned that cycle; may hasten ovulation and resolution but it is not effective if given after ovulation

Precautions/Interactions

- Avoid progestational drugs due to risk of inducing pyometra.



■ **Figure 110.2** Severe vaginal hyperplasia with urinary catheter in place.

Activity

- Keep confined in clean area to prevent tissue damage
- Apply Elizabethan collar to prevent self-trauma
- Separate from other dogs to prevent trauma

Surgical Considerations

- If ability to urinate is compromised or tissue is necrotic, surgical resection is necessary.
- If recurs near end of gestation, delivery of fetuses by Caesarian section may be necessary.



COMMENTS

Client Education

- Keep prolapsed tissue clean and moist
- Monitor ability to urinate
- Consider removing from breeding program due to genetic basis
- Breed via artificial insemination if breeding still desired
- Monitor again near end of diestrus/gestation for recurrence
- If recurs near end of gestation, Caesarian section may be needed

Patient Monitoring

- Recheck if any concern about viability of tissue
- Recheck if owner notes inability to urinate

Prevention/Avoidance

- Ovariohysterectomy is recommended.

Possible Complications

- Urethral compromise and inability to urinate
- Necrosis of prolapsed tissue

Expected Course and Prognosis

- Tissue regresses with time and decrease in estrogen.
- If not spayed, may recur at end of gestation/diestrus
- If not spayed, typically will recur at next proestrus
- Ovariohysterectomy prevents recurrence later in cycle or in future.
- Prognosis for recovery good, except with urethral involvement
- Surgical intervention for type III: prognosis good

Abbreviations

- GnRH: gonadotropin-releasing hormone
- hCG: human chorionic gonadotropin
- IM: intramuscularly

Suggested Reading

- Feldman, EC, and Nelson, RW. Vaginal defects, vaginitis, and vaginal infections. In: Feldman, EC, Nelson, RW, eds. *Canine and Feline Endocrinology and Reproduction*, pp. 901–928. Philadelphia, Saunders, 2004.
- Johnston, SD, Root Kustritz, MV, and Olson, PNS. Disorders of the canine vagina, vestibule, and vulva. In: Johnston, SD, Root Kustritz, MV, and Olson, PNS, eds. *Canine and Feline Theriogenology*, pp. 225–242. Philadelphia: Saunders, 2001.
- Memon, MA, Pavletic, MM, and Kumar, MSA. Chronic vaginal prolapse during pregnancy in a bitch. *J Am Vet Med Assoc* 1993;202:295–297.
- Post, K, Van Haaften, BV, and Okkens, AC. Vaginal hyperplasia in the bitch: literature review and commentary. *Can Vet J* 1991;32:35–37.

Author: Joni L. Freshman

Ventricular Dysrhythmias

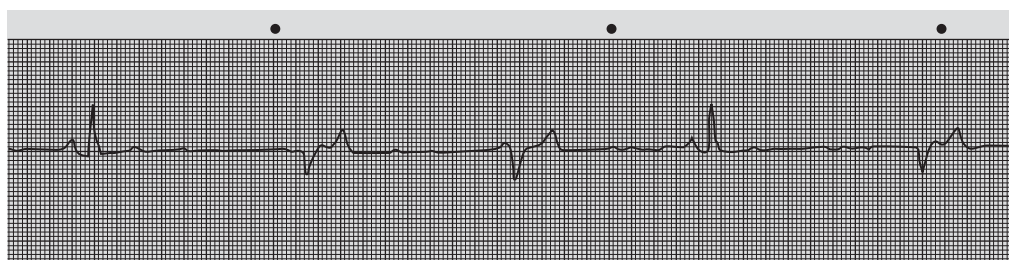


DEFINITION/OVERVIEW

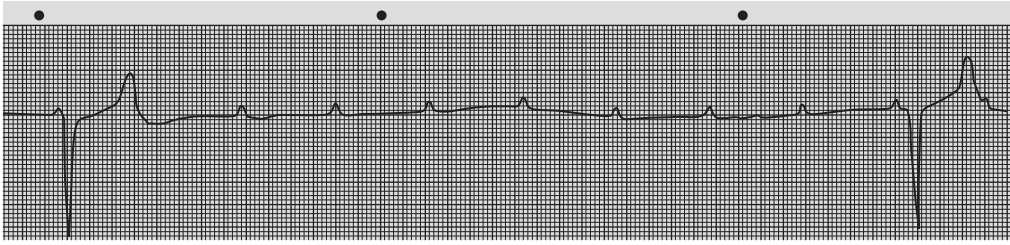
- If conduction of sinus node pacemaker impulses to the ventricles is blocked or the impulses decrease in frequency, the lower regions of the heart automatically take over the role of pacemaker for the ventricles, which results in ventricular escape complexes (Figure 111.1) or an idioventricular rhythm (Figure 111.2).

Features

- A series of ventricular escape beats with a heart rate < 65 beats per minute in dogs and <100 beats per minute in cats; heart rates of 65 to 100 beats per minute in dogs and 100 to 160 beats per minute in cats are often termed *accelerated idioventricular rhythms*.
- P waves may be absent or may precede, be hidden within, or follow the ectopic QRS complex.
- P waves are unrelated to the QRS complexes.
- QRS configuration is wide and bizarre; similar to that of a ventricular premature complex



■ **Figure 111.1** Ventricular escape complexes during various phases in the dominant sinus rhythm in a dog during anesthesia. The sinus rate increased (*not shown*) after anesthesia was stopped; 1/2 cm1 mv. Source: Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Ames, IA: Blackwell Publishing, 1992, with permission.



■ **Figure 111.2** Complete heart block. The P waves occur at a rate of 120, independent of the ventricular rate of 50. The QRS configuration is a right bundle branch block pattern. The regular rate and stable QRS indicate that the rescuing focus is probably near the AV junction.

Source: Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed. Ames, IA: Blackwell Publishing, 1992, with permission.



ETIOLOGY/PATHOPHYSIOLOGY

- May be hemodynamically important with slow ventricular rates
- Does not occur in healthy animals
- Subsidiary pacemakers seem to discharge more rapidly in cats than in dogs.

Risk Factors/Causes

- Not a primary disease; a secondary result of a primary disease
- The escape rhythm is a safety mechanism to maintain cardiac output.
- Causes of sinus bradycardia and sinus arrest
- Increased vagal tone (i.e., high intracranial pressure, high ocular pressure)
- Drugs: digoxin, tranquilizers, propranolol, quinidine, and anesthetics
- Addison's disease
- Hypoglycemia
- Renal failure
- Hypothermia
- Hyperkalemia
- Hypothyroidism
- Causes of AV block
- Congenital
- Neoplasia
- Fibrosis
- Lyme disease

Systems Affected

- Cardiovascular



SIGNALMENT/HISTORY

Species

- Dogs and cats

Breed Predilections

- Atrial standstill in English springer spaniels and Siamese cats
- Pugs, miniature schnauzers, and Dalmatians prone to conduction abnormalities

Historical Findings

- Some animals asymptomatic
- Weakness
- Lethargy
- Exercise intolerance
- Syncope
- Heart failure



CLINICAL FEATURES

Physical Examination Findings

- Irregular rhythm associated with pulse deficits
- Variation in heart sounds
- Possible intermittent “cannon” waves in the jugular venous pulses (with AV block)



DIFFERENTIAL DIAGNOSIS

- Ventricular tachycardia—dogs have a cardiac rate > 100 beats per minute; cats > 150 bpm
- Slow heart rate in animals with right bundle branch block, left bundle branch block, or left anterior fascicular block; animals with these disturbances have the P waves associated with the QRS complexes.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- No specific findings
- Complete blood testing may suggest a metabolic abnormality.

Other Laboratory Tests

- Drug toxicity
- Lyme's titer in animals with complete AV block

Imaging

- Echocardiogram may show structural heart disease.

Diagnostic Procedures

- Electrocardiography

Pathological Findings

- Depend on underlying cause



THERAPEUTICS

Drug(s) of Choice

- Atropine or glycopyrrolate usually indicated to block vagal tone or increase the heart rate
 - If those drugs are ineffective, isoproterenol, dopamine, dobutamine, or artificial pacing may be needed.

Contraindications

- Lidocaine, procainamide, quinidine, propranolol, diltiazem, or any other drug that slows the cardiac rate or reduces contractility

Precautions/Interactions

- Atropine is briefly vagotonic immediately postinjection and can temporarily exacerbate the condition.

Diet

- No modifications or restrictions unless required for management of the underlying condition.

Activity

- Symptomatic animals may require cage rest.

Surgical Considerations

- Pacemaker implantation may be necessary.

Appropriate Health Care

- Rhythm is an escape or safety mechanism for maintaining cardiac output; do *not* direct treatment toward suppressing this escape rhythm, but toward the primary disease process that allows the escape rhythm to assume pacemaker control of the heart.
- Symptomatic treatment is directed toward increasing the heart rate.

Nursing Care

- May be required for underlying disease



COMMENTS

Client Education

- Inform of the need to seek and specifically treat an underlying cause.

Patient Monitoring

- Serial ECG may show clearing of the lesion or progression to complete heart block.
- Serial blood profiles may be needed to monitor progress of the primary disease process.
- Serial echocardiograms may show improvement or progressive changes in cardiac structure.

Possible Complications

- Prolonged bradycardia may cause secondary congestive heart failure or inadequate renal perfusion.

Expected Course and Prognosis

- Arrhythmia may abate when the primary disorder is corrected.
- Guarded if condition is associated with cardiac or metabolic disorder; poor if the rate is not increased pharmacologically or if underlying cause cannot be identified and treated

Abbreviations

- AV: atrioventricular
- ECG: electrocardiogram

See Also

- Atrioventricular Block

Suggested Reading

Kittleson, MD. Electrocardiography. In: Kittleson, MD, and Kienle, RD, eds. *Small Animal Cardiovascular Medicine*, 72–94. St. Louis: Mosby, 1998.

Tilley, LP. *Essentials of Canine and Feline Electrocardiography*, 3rd ed., pp. 152, 222. Ames, IA: Blackwell Publishing, 1992.

Tilley, LP, Smith, FWK, Oyama M, and Sleeper, M. *Manual of Canine and Feline Cardiology*, 4th ed. St. Louis: Saunders/Elsevier, 2008.

Author: Larry P. Tilley

Vomiting and Hematemesis



DEFINITION/OVERVIEW

- Vomiting blood



PATHOPHYSIOLOGY/ETIOLOGY

- Blood may be vomited because of (a) mucosal disruption (ulcer/erosion) in esophageal, gastric, intestinal, or gall bladder mucosa, (b) coagulopathy, or (c) patient swallowing blood originating from either inside (e.g., mouth, nose, or lungs) or outside the body.

Causes of Gastric Ulceration/Erosion

Drugs

- Newer COX-2 selective NSAIDs are safer than older, nonselective NSAIDs but can still cause GUE.
- Dexamethasone is probably the most ulcerogenic of commonly used steroids.
- Prednisolone is much less ulcerogenic unless there are other, additional factors favoring GUE.

Gastritis

- Often idiopathic
- May be caused by ingestion of toxic/irritative substances (e.g., heavy metals, fertilizer, etc).
- *Helicobacter* spp. are not considered a cause of canine or feline GUE.
- Pythiosis causes mucosal disruption and GUE.
- Gastric foreign bodies occasionally cause GUE and bleeding, but they inhibit healing of GUE from any other cause.
- Inflammatory bowel disease has been associated with GUE, but cause and effect are uncertain.
- “Stress”/poor perfusion/shock—probably due to poor visceral perfusion coupled with increased endogenous steroids.
- Gastric hyperacidity—paraneoplastic effect from mast cell tumors and gastrinomas.

- Gastric and duodenal neoplasia—mechanically disrupt gastric mucosa. Leiomyomas are most important cause, but other tumors occasionally responsible.
- Iatrogenic—improper surgical closure of gastrotomy incisions.

Other Diseases Causing Gastrointestinal Hemorrhage

- Hookworms—Severe infestations cause upper duodenal bleeding with duodenal-gastric reflux.
- Hemorrhagic gastroenteritis—Uncertain cause but assumed to be immune- or bacterial-induced.
- Hepatic disease—Severe hepatic failure often associated with GUE by uncertain mechanisms.
- Pancreatitis—Duodenal hemorrhage in severe cases when there is severe inflammation by direct extension.
- Renal failure—Not as important as previously thought.
- Hypoadrenocorticism—Rare but important; mimics primary GI disease; assume mucosal disruption due to lack of steroids.
- Esophagitis—Ulcers/erosions due to foreign bodies, caustic substances (e.g., tetracycline) or gastroesophageal reflux of acid.

Causes of Coagulopathies

- Thrombocytopenia (numerous causes)
- von Willebrand's disease
- Vitamin K antagonism
- DIC
- Congenital defects

Causes of Ingestion of Blood

- Endogenous blood: coughing blood up from airway, swallowing and then vomiting it (all without hemoptysis) can be due to airway disease, nasal or bronchopulmonary tumor, pneumonia, heartworms, fungal infections.
- Swallowing blood has escaped from the nose posteriorly via the choana.
- Exogenous blood: blood from any outside source (e.g., food, lacerations, anal sacs) may be ingested and later vomited.

Systems Affected

- Gastrointestinal—Inflammation, trauma, ulceration, neoplasia or foreign body in the oral cavity, esophagus, stomach or duodenum causes anorexia, vomiting, or regurgitation.
- Cardiovascular—Acute, severe hemorrhage causes tachycardia, systolic heart murmur, or hypotension.
- Respiratory—Respiratory hemorrhage with ingestion causes hematemesis, tachypnea due to severe hemorrhage (shock), aspiration pneumonia, or pulmonary infiltrative disease.

- Hemic/Lymphatic/Immune—Coagulopathy causing GI hemorrhage can cause hematemesis.



SIGNALMENT/HISTORY

Risk Factors/Causes

- Dogs more commonly affected than cats.
- No recognized genetic, breed, age, or sex predilections.
- Animals more likely to receive NSAIDs are probably at increased risk for GUE.

Historic Findings

- Vomiting blood—may appear as fresh (red; Figure 112.1) or digested (coffee grounds; Figure 112.2) blood. Minimal bleeding due to mucosal trauma from vigorous vomiting may cause small “flecks” of blood. Not all dogs with upper GI bleeding vomit blood or even vomit.
- Melena—Black, tarry stools; only seen when large amount of blood enters GI tract in relatively short time. Much less common than hematemesis
- Anorexia—Very common sign of gastric disease, even in absence of vomiting
- Abdominal pain—May assume “praying position” (infrequent)
- Weakness/respiratory distress—Either/both can be seen with severe anemia
- Coagulopathy—May see petechiation, ecchymosis, hyphema or epistaxis



■ **Figure 112.1** Frank blood in vomitus from a patient with hemorrhagic gastroenteritis.



■ **Figure 112.2** Digested blood in a large amount of vomitus from a Rottweiler with immune-mediated thrombocytopenia and subsequent gastrointestinal bleeding. Note the “coffee-ground” appearance of the vomitus.



CLINICAL FEATURES

Dogs

- Anemic patients: pale oral mucous membranes, tachypnea, systolic heart murmur, weakness (especially in rear legs in dogs), sometimes collapse.
- Abdominal pain—inconsistent finding; can be subtle.
- Melena—very infrequent.
- Coagulopathy—petechiations, ecchymoses, hematochezia, epistaxis, retinal hemorrhage, hyphema, or hematuria.
- Edema—infrequent; only when serum albumin < 1.6 g/dl.

Cats

- Similar to dogs, but less frequent.



DIFFERENTIAL DIAGNOSIS

Dogs

- Hemoptysis—history may allow differentiation. Thoracic radiographs usually reveal thoracic/airway lesions.

- Regurgitation of blood—primarily from ingestion of blood or severe esophagitis or trauma from foreign objects. Plain/contrast radiographs of esophagus often diagnose foreign objects. Esophagoscopy is most sensitive test for esophagitis.
- Ingestion and vomiting of foreign material or food that looks like blood (e.g., iron products).
- Melena can be mimicked by oral administration of bismuth subsalicylate.

Cats

- Same as but less frequent than for dogs.



DIAGNOSTICS

Complete Blood Count/Biochemistry/Urinalysis

- Acute hemorrhage (<3 days) causes nonregenerative anemia plus hypoalbuminemia.
- Anemia that >5 days old causes regenerative anemia (reticulocytosis, increased MCV) in patients not iron deficient, plus hypoalbuminemia.
- Chronic iron deficiency anemia causes poorly regenerative, microcytic anemia with hypoalbuminemia (i.e., low total serum iron concentration).
- Panhypoproteinemia may or may not be found, depending on serum globulin concentration before blood loss.
- Thrombocytosis may occur with chronic iron deficiency; thrombocytopenia may cause bleeding diathesis.
- Nonspecific findings include neutrophilic leukocytosis.
- BUN-to-creatinine ratio: Hemorrhage may increase BUN disproportionately compared to serum creatinine concentration; BUN raised by high protein meals (e.g., blood) requires major hemorrhage in relatively short period of time.
- Hepatic failure caused by cirrhosis may/may not have increased ALT or bilirubin, usually causes hypoalbuminemia.
- Hypoadrenocorticism may or may not cause electrolyte abnormalities (hyponatremia/hyperkalemia), hypercalcemia, hypoglycemia, or inappropriate lymphocytosis or eosinophilia in stressed dogs.

Special Blood Tests

- Pancreatic lipase immunoreactivity appears to be most sensitive test for pancreatitis, but specificity is uncertain.
- Resting serum cortisol concentration is acceptable screen for patients most likely to benefit from ACTH-stimulation testing.
- Serum gastrin needed to diagnose gastrinomas.
- Pre- and postprandial serum bile acids or blood ammonia for hepatic insufficiency.
- Coagulation profiles for coagulopathies.
- Serology/PCR for pythiosis.

- Fecal flotation for *Ancylostoma* ova.
- Buccal mucosal bleeding time is a reasonable screening test for coagulopathies severe enough to cause GI bleeding.

Imaging

- Abdominal radiographs may reveal foreign objects or spontaneous pneumoperitoneum (i.e., gastrointestinal perforation or septic peritonitis).
- Abdominal ultrasound more revealing and can demonstrate thickened infiltrated areas, ulcers, scant amounts of free fluid, foreign objects, hepatic disease, or pancreatitis. Ultrasound can guide fine needle aspiration of apparently infiltrated areas or small pockets of fluid for fluid analysis and cytology.
- Upper GI contrast radiographs not recommended in GI patients with upper GI hemorrhage except possibly when looking for esophageal foreign bodies or inflammation.
- Thoracic radiographs may reveal foreign bodies or pulmonary lesions.

Pathologic Findings

- Gastroduodenoscopy is most sensitive for finding lesions between mouth and distal duodenal flexure. Once coagulopathy is eliminated, biopsies should routinely be obtained of any lesion; gross appearances may be deceiving.
- Infiltrated lesions may be inflammatory or neoplastic.
- Lesions may be very sporadic necessitating endoscopic guidance of the biopsies to maximize chance of diagnosis.



THERAPEUTICS

- The first goal is to stop GI bleeding; next is to stop clinical signs (e.g., anorexia, vomiting) and resolve lesion to minimize chance of perforation.

Drug(s) of Choice

- Drugs are often ineffective if cause (e.g., NSAID drugs, poor perfusion) is not removed; important to remove cause while treating medically.
- H₂ receptor antagonists are most commonly used drugs.
 - Cimetidine is least potent and has most side effects.
 - Famotidine is most potent H₂ receptor antagonist (0.5 mg/kg PO or IV, every 12–24 hours).
 - Ranitidine (1–4 mg/kg PO or IV every 8–12 hours) and nizatidine (2.5–5 mg/kg PO every 24 hours) are supposed to have gastric prokinetic activity. Ranitidine is of uncertain value in raising gastric pH. Length of treatment depends upon cause. If no clinical response seen within 7 days, reevaluate patient and therapy.
- Proton pump inhibitors are noncompetitive inhibitors of gastric acid secretion and more effective than H₂ receptor antagonist; principal use is for gastrinomas and

esophagitis. Requires 2 to 5 days to achieve maximal efficacy when administered orally.

- Omeprazole (0.7–1.5 mg/kg PO every 12–24 hours) is most commonly prescribed.
- Lansoprazole and pantoprazole have anecdotally been given IV at 1 mg/kg once daily.
- Orally administered antacids (e.g., aluminum hydroxide) may require six or more daily administrations to achieve same degree of acid control as H₂ receptor antagonists or proton pump inhibitors.
- Sucralfate (0.5–1 g PO every 12–24 hours) binds to ulcer sites, stimulates healing and protects them.
- Misoprostol—Prostaglandin analog developed as a prophylaxis against NSAID-induced GUE. Can be used to treat GUE (2–5 µg/kg PO every 8 to 12 hours) as well as prevent it. It may initially cause diarrhea or abdominal cramping.
- Antiemetics may be used symptomatically, as necessary:
 - Ondansetron (0.5–1 mg/kg PO or 0.1–0.2 mg/kg IV every 12–24 hours)
 - Dolasetron (0.6–1 mg/kg IV or SQ every 24 hours)
 - Maropitant (1 mg/kg SQ every 24 hours or 2 mg/kg PO every 24 hours).
- Amoxicillin (22 mg/kg PO every 12 hours) plus metronidazole (15 mg/kg PO every 24 hours) plus famotidine (0.5 mg/kg PO every 24 hours) generally effective against *Helicobacter* spp. found in dogs and cats; but, *Helicobacter* is doubtful cause of canine or feline GUE.

Precautions/Interactions

- Cimetidine inhibits hepatic P450 enzymes.
- Sucralfate may inhibit absorption of some other orally administered drugs.
- NSAIDs are potentially catastrophic in GUE patients.

Surgical Considerations

- If GI bleeding due to suspected GUE does not show evidence of improvement within 5 to 7 days of starting medical therapy *or* if GI blood loss is so severe that waiting for medical therapy puts patient at inappropriate risk, one should perform endoscopy to see if responsible lesion(s) appear(s) resectable. Leiomyomas are potentially resectable and should be removed as soon as possible. Patients apparently in danger of perforating should have lesions resected, if possible.



COMMENTS

Client Education

- All NSAIDs increase GUE risk; if NSAIDs have caused GI bleeding once before, they must be used cautiously under supervision of veterinarian.

Patient Monitoring

- Clinically monitoring patient (i.e., attitude, mucous membrane color, abdominal pain, vomiting, appetite) is usually sufficient to determine efficacy of medical therapy.
- Animals with especially low hematocrits (i.e., <20 percent in dog; <18 percent in cat) must be monitored closely; serial hematocrits may be appropriate. Repeat endoscopy is seldom necessary in patients that are clearly improving clinically.

Prevention/Avoidance

- Avoid (a) concurrent administration of NSAIDs and steroids; (b) concurrent use of two NSAIDs; (c) large doses of dexamethasone; (d) large doses of any steroid or NSAID in poorly perfused or hypoxic patients.

Possible Complications

- GUE perforation causes septic peritonitis. Vomiting sometimes associated with aspiration pneumonia. Severe blood loss necessitates administration of red blood cells or purified bovine hemoglobin.
- Misoprostol (a synthetic prostaglandin) causes abortion in pregnant animals.

Expected Course and Prognosis

- Prognosis depends on cause.
- GUE due to NSAIDs and dexamethasone can usually be resolved.
- Gastric malignancies have extremely poor prognosis; but leiomyomas are often cured with surgical resection.
- Paraneoplastic hyperacidity (gastrinomas and mast cell tumors) often palliated for months to a year.
- Severe hepatic failure and gastric pythiosis have guarded to very poor prognosis, respectively.
- Hypoadrenocorticism has excellent prognosis if diagnosed and treated in a timely fashion.

Abbreviations

- ACTH: adrenocorticotrophic hormone
- ALT: alanine transferase
- BUN: blood urea nitrogen
- DIC: disseminated intravascular coagulation
- GI: gastrointestinal
- GUE: gastroduodenal ulceration
- IM: intramuscularly
- IV: intravenously
- MCV: mean corpuscular volume
- NSAIDs: nonsteroidal anti-inflammatory drugs
- PCR: polymerase chain reaction

- pH: acid-base
- PO: by mouth
- SQ: subcutaneously

Suggested Reading

- Dowers, K, Uhrig, S, Mama, K, et al. Effect of short-term sequential administration of nonsteroidal anti-inflammatory drugs on the stomach and proximal portion of the duodenum in healthy dogs. *Am J Vet Res* 2006;67:1794–1801.
- Peters, R, Goldstein, R, Erb, H, et al. Histopathologic features of canine uremic gastropathy: a retrospective study. *J Vet Inter Med* 2005;19:315–320.
- Waldrop, JE, Rozanski, EA, Freeman, LM, et al. Packed red blood cell transfusions in dogs with gastrointestinal hemorrhage: 55 cases (1999–2001). *J Am Anim Hosp Assoc* 2003;39:523–527.
- Willard, MD. How to refer gastric ulceration/erosion. *Clinician's Brief* 2006;4:2–26.
- Willard, MD. Gastrointestinal haemorrhage. In: Hall, EJ, Simpson, JW, and Williams, DA, eds. *BSAVA Manual of Canine and Feline Gastroenterology*, 2nd ed., pp. 91–93. Quedgeley, Gloucester: BSAVA, 2005.

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von Willebrand Disease (vWD)



DEFINITION/OVERVIEW

- vWD is a qualitative or quantitative deficiency in vWF, causing a dysfunctional interaction between platelets and vascular collagen (primary hemostasis), thereby reducing the adherence of platelets to sites of vascular injury.
- The most common inherited bleeding disorder in dogs, with inheritance being influenced by vWD type.



ETIOLOGY/PATHOPHYSIOLOGY

- Clinical manifestations are brought about by a reduction in two of the established functions of vWF; first, its role in supporting adhesion of platelets to damaged blood vessels (specifically subendothelial collagen), and second, postsynthetic association of vWF with factor VIII that protects factor VIII from proteolysis.
- The disease has been divided into three different major types.
- Type 1 vWD is characterized by a partial quantitative deficiency of all vWF sizes that have a normal multimeric structure; most frequently documented type with clinical signs indirectly correlated with reduction in plasma vWF.
- Type 2 vWD is characterized by both a quantitative and qualitative deficiency of vWF, with the quantitative deficiency primarily affecting the larger (more hemostatically active) multimers; least commonly diagnosed variant in animals.
- Type 3 vWD is the most fatal type, due to a severe quantitative deficiency (vWF:Ag <1 percent) of vWF.
- Type 3 vWD is associated with the most severe hemorrhage, whereas type 1 vWD generally manifests with the least severe hemorrhage.

Systems Affected

- Gastrointestinal—Bleeding during teething or mucosal hemorrhage
- Hemic/lymphatic/Immune—Anemia if hemorrhage is severe
- Renal/Urologic—Hematuria
- Reproductive—Prolonged estral hemorrhage
- Respiratory—Epistaxis
- Skin/Exocrine—Hemorrhage from wounds or surgical sites, cutaneous bruising, or rarely petechia



SIGNALMENT/HISTORY

- No sex predilection
- Most patients affected from birth
- Type 1: many canine breeds (Doberman pinschers, Airedales, shelties); Himalayans
- Type 2: German wirehaired pointer, German shorthaired pointer
- Type 3: Scottish terrier, Shetland sheepdog; domestic longhair and domestic short-hair felines

Risk Factors/Causes

- Hypothyroidism has been found to be associated with vWD in dogs.
- Known familial inheritance.

Historical Findings

- Bleeding may or may not be a historical feature.
- Excessive hemorrhage noted at the time of teething, during estrus or secondary to minor injury.
- Sometimes familial inheritance is known.



CLINICAL FEATURES

- Symptoms related to deficiency in primary hemostasis, such as spontaneous mucosal hemorrhage (i.e., epistaxis, hematuria, GI hemorrhage), more commonly overt hemorrhage after trauma or during teething or surgery; mild to moderate bleeding is typical.
- Petechiation is uncommon in dogs and cats.



DIFFERENTIAL DIAGNOSIS

- Thrombocytopenia
- Inherited (Glanzmann's thrombasthenia, etc.) or acquired (aspirin therapy, etc.) thrombocytopathies



DIAGNOSTICS

- Different subtypes of vWD require slightly different diagnostic strategies.
- Prolonged BMBT with normal platelet count is typical, however BMBT is not sensitive enough to consistently detect mild vWD and a normal result does not rule out the disease; in addition, clinical utility is limited by problems with standardization of the procedure.

TABLE 113.1 Selected laboratory features of von Willebrand disease types

| vWD | Factor VIII | vWF:Ag | Multimer structure |
|--------|---------------------|---------------------|----------------------------|
| Type 1 | Decreased | Decreased | Normal |
| Type 2 | Decreased or normal | Decreased or normal | Larger multimers decreased |
| Type 3 | Moderate decrease | Absent or trace | None or trace |

vWD, von Willebrand disease; vWF, von Willebrand factor.

- Definitive diagnosis requires confirmation of low vWF:Ag with types 1 and 3, but may be normal in type 2 (see Table 112.1).
- The PT is usually normal, whereas aPTT may be prolonged due to reduced levels of plasma factor VIII because the plasma level factor VIII depends on vWF level, patients with milder forms of vWD usually have normal levels of factor VIII.
- Being an acute phase reactant, transiently increased levels during hemorrhage may obscure the diagnosis, therefore, if possible, tests should not be performed in proximity to hemorrhagic events, acute infection, pregnancy, or strenuous exercise.
- If a laboratory diagnosis of vWD is made in an older canine patient with only a recent history of clinical signs, consider evaluating for hypothyroidism.

Pathological Findings

- Hemorrhage possible at any site, but most commonly associated with areas of trauma or surgery.



THERAPEUTICS

- Different types of vWD require slightly different therapeutic strategies.

Drug(s) of Choice

- DDAVP is the treatment of choice in type 1 vWD, used to transiently increase the endogenous release of factor vWF from endothelial storage sites, as well as increase factor VIII.
- Use of DDAVP may avoid transfusion in patients requiring only temporary normalization of primary hemostasis (i.e., patients undergoing brief invasive procedures).
- Cryoprecipitate (concentrated form of vWF and factor VIII) may be used to replace vWF in all three types of vWD.

Precautions/Interactions

- Tachyphylaxis rapidly occurs to DDAVP limiting its usefulness to just a few doses.
- Free water retention after DDAVP administration rarely leads to volume overload or hyponatremia.

- Increasing risk of immunologic transfusion reactions with chronic repeated administration of allogenic blood products.
- Acute administration of FFP may predispose to circulatory overload.

Alternative Drugs

- FFP may be used to provide vWF, if cryoprecipitate is not available.
- Administration of DDAVP to the blood donor, prior to unit collection, increases the level of vWF in the donated unit.
- Thyroid supplementation if concomitant hypothyroidism exists.
- Site-specific therapy may be necessary (i.e., direct pressure, use of hemostatically active agents, or surgical hemostasis).

Activity

- Limit activity in patients shown to manifest with spontaneous hemorrhage.

Surgical Considerations

- Prophylactic vWF replacement prior to invasive procedures or at least have appropriate blood products readily available.
- Avoid elective procedures, but if necessary, maximize surgical hemostasis techniques.



COMMENTS

Client Education

- Review mode of inheritance and discuss appropriate breeding practices; animals with clinical hemorrhage should not be used for breeding, asymptomatic carriers would preferably not be utilized or at a minimum be bred only with cleared partners.
- Recommend diagnostic testing for related animals.
- Herbal supplements, notably garlic, ginkgo, and ginseng, may exacerbate hemorrhagic tendencies.

Patient Monitoring

- Screening is important for breeds with a high prevalence.
- BMBT is an insensitive tool for monitoring therapeutic response.
- Evaluate fluid and electrolyte status if DDAVP was administered.
- Closely observe for hemorrhagic events, especially following surgical or accidental trauma.

Prevention/Avoidance

- Avoid breeding affected animals.

- Conscious measures are taken to limit risk of hemorrhage (i.e., conservative nail trims, etc.).

Possible Complications

- Hemorrhage, especially with concurrent medical conditions known to influence primary hemostasis (i.e., thrombocytopenia, uremia, hepatic disease, etc.) or administration of medications known to inhibit platelet function (aspirin or other nonsteroidal anti-inflammatories, phenothiazine tranquilizers, synthetic colloids, etc.).

Expected Course and Prognosis

- Disease is medically managed, but not cured.
- Hemorrhage may be fatal or is controlled with appropriate therapy.
- Long-term prognosis varies with vWD type that the animal has.

Abbreviations

- aPTT: activated partial thromboplastin time
- BMBT: buccal mucosal bleeding time
- DDAVP: desmopressin or 1-deamino-8-D-arginine vasopressin
- FFP: fresh frozen plasma
- GI: gastrointestinal
- PT: prothrombin time
- vWD: von Willebrand disease
- vWF: von Willebrand factor
- vWF:Ag: quantified plasma concentration of vWF

Suggested Reading

Brooks, M. von Willebrand disease. In: Feldman, BF, Zinkl, JG, and Jain, NC. *Schalm's Veterinary Hematology*, 5th ed., pp. 509–515. Baltimore: Williams & Wilkins, 2000.

Smith, JW, Day, TK, and Mackin, A. Diagnosing bleeding disorders. *Compend Contin Educ Pract Vet* 2005;27(11):828.

Author: Todd Duffy

Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Michael J. Murphy

Zinc Toxicity



DEFINITION/OVERVIEW

- Toxicity from the ingestion of zinc containing objects, most commonly U.S. pennies minted after 1982
- Causes severe intravascular hemolysis, gastrointestinal irritation, renal injury; may lead to multiple organ failure, DIC and cardiopulmonary arrest; pancreatitis can occur as a possible sequela



ETIOLOGY/PATHOPHYSIOLOGY

- The stomach's acidic environment mediates the rapid release of zinc from ingested foreign materials; rate of zinc release depends on gastric pH, presence or absence of food/ingesta, and the length of time foreign objects are in stomach.
- After absorption, zinc is transported to the liver and excreted through feces and pancreatic secretions.
- Exact mechanism of zinc-mediated hemolysis and zinc-mediated renal injury are unknown.

Systems Affected

- Hemtic: Zinc toxicity induces severe intravascular hemolysis.
- Renal/Urologic: Zinc mediated renal injury possibly secondary to anemia, hypoxia, or direct tubular injury
- Gastrointestinal: Direct irritation and corrosive effects from presence of metallic object/zinc in stomach or intestinal lining; pancreatitis is also possible.
- Cardiovascular/Respiratory: Zinc toxicosis sequela includes DIC and cardiopulmonary arrest from severe hypoxia, anemia, and multiple organ failure
- Hepatobiliary: Zinc is transported to the liver and can cause hepatocellular damage.
- Nervous: There is one report of zinc neurotoxicity in a puppy possibly caused by secondary hypoxia and neuronal ischemia.



SIGNALMENT/HISTORY

- Due to the higher incidence of dietary indiscretion in dogs, they are the most commonly reported species for zinc toxicity with no sex or age predilections.



■ **Figure 114.1** Penny ingested by a beagle puppy. Note that the penny, which was minted after 1982, was degraded significantly by gastric acid.



■ **Figure 114.2** Coins ingested by a beagle puppy.

Risk Factors/Causes

- Ingestion of zinc containing objects such as U.S. pennies minted after 1982 (Figures 114.1 and 114.2), galvanized metal, plumbing parts, and zinc oxide ointments

Historical Findings

- Most penny ingestions are not witnessed and the most commonly reported clinical signs by owners include: depression, vomiting, weakness, abdominal pain, icterus, and signs of renal failure



CLINICAL FEATURES

- Signs of intravascular hemolysis include: icterus, weakness, depression, pale mucous membranes, and hematuria/hemoglobinuria
- Signs of gastrointestinal irritation include: vomiting/hematemesis, diarrhea/hematochezia/melena, anorexia, abdominal pain; or signs of acute pancreatitis
- Signs of acute toxic renal failure include: PU/PD, oliguria or anuria, vomiting, depression, weakness, or anorexia



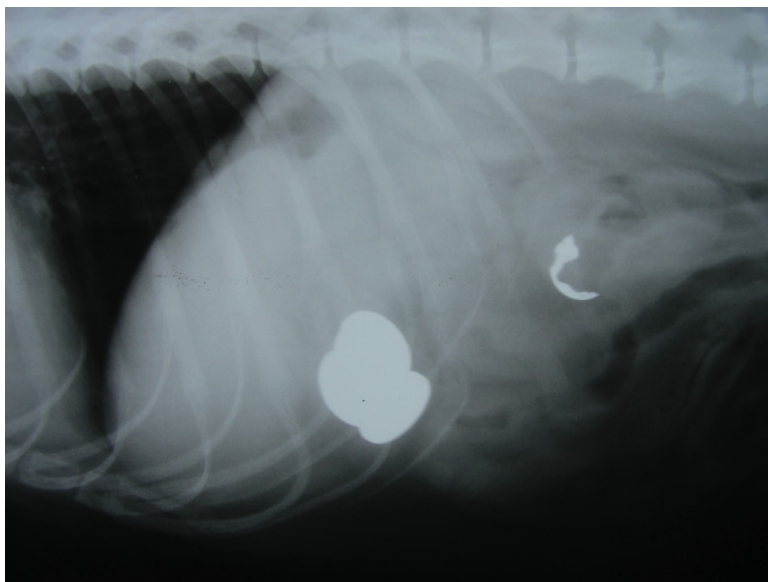
DIFFERENTIAL DIAGNOSIS

- Differential diagnosis includes any other causes of hemolytic anemia such as immune-mediated hemolytic anemia, tick-borne diseases, allium (chive, garlic, leek, onion, shallot) toxicity, toxicity from other metals (lead, copper); infectious disease (i.e., hemobartonellosis, heartworm disease, leptospirosis, and feline leukemia virus infection), neoplasia, and splenic torsion.



DIAGNOSTICS

- The diagnosis of zinc toxicity is usually based on clinical signs and radiographic identification of metallic objects in the gastrointestinal tract (Figure 114.3).
- Biochemical abnormalities:
 - Hemolysis: moderate to severe regenerative anemia, bilirubinemia, bilirubinuria, hemoglobinemia, and hemoglobinuria
 - Renal failure: azotemia, hyposthenuria
 - RBC abnormalities: nucleated RBC, basophilic stippling, target cells, polychromasia
 - Evidence of multiple organ failure: elevated ALT, ALP, coagulation abnormalities (prolonged PT, PTT, high FDP, thrombocytopenia, elevated D-dimers)



■ **Figure 114.3** Lateral abdominal radiograph from the beagle puppy, demonstrating coins in the stomach and small intestine.

- Zinc concentrations of serum or urine: dog normal is 0.7 to 2.0 ppm, a concentration above 10 ppm is diagnostic for zinc toxicity.
- Zinc toxicosis may cause a positive outcome for a Coombs' test in the absence of a primary autoimmune disorder.

Pathological Findings

- Postmortem changes include tubular nephrosis; centrolobar to midzonal hepatic necrosis, vacuolar degeneration; pancreatic inflammation, necrosis, and fibrosis; gastrointestinal hyperemia and serositis and scattered neuronal shrinkage associated with hypoxia.



THERAPEUTICS

- Goals of therapy include patient stabilization, minimizing zinc absorption via the removal of the metallic object, supportive care for subsequent hemolysis and renal failure.
- Initial patient stabilization includes treatment of shock with intravenous crystalloid fluids, supplemental oxygen therapy, blood or bovine hemoglobin glutamer (Oxyglobin®) transfusions, antiemetic, and gastroprotectant drugs.
- Removal of the zinc containing object is critical and may be achieved with emesis in asymptomatic patients. Surgical or endoscopic removal may be required, depending on location of the foreign body.

Drug(s) of Choice

- H₂-receptor blockers help reduce zinc absorption by decreasing gastric acidity (Famotidine 0.5 mg/kg PO, SQ, or IV).
- Proton pump inhibitors
- Diuresis with a balanced crystalloid solution is indicated to address dehydration, prevent hemoglobinuric nephrosis, and promote renal excretion of zinc at twice maintenance rate.
- Activated charcoal is *not* recommended because it is ineffective in adsorbing elemental zinc.
- Sucralfate (0.5–1.0 g orally two to three times daily) after removal of zinc containing object as a gastroprotectant
- Antiemetics for gastrointestinal upset (Dolasetron 0.6–1.0 g/kg IV every 24 hours, Ondansetron 0.1–0.2 mg/kg IV every 6–12 hours; 0.1–1 mg/kg PO every 12 hours, Metoclopramide hydrochloride 0.2–0.4 mg/kg PO, SQ, or IV constant rate infusion at 1–2 mg/kg per day)
- Transfusions: Packed RBC transfusions (10 ml/kg) after blood typing, Oxyglobin® (Biopure, 15 ml/kg in dogs, 2 to 5 ml/kg in cats); fresh frozen plasma (10 ml/kg) in cases in which pancreatitis or coagulopathy are evident
- Chelation therapy is controversial as it may increase gastrointestinal absorption and potential for nephrotoxicity.
 - Calcium EDTA: 25 mg/kg SQ every 6 hours for 2 to 5 days
 - Oral penicillamine 35 mg/kg four times daily for 7 to 14 days

Surgical Considerations

- Surgical or endoscopic removal of the zinc containing objects may need to be attempted; care to stabilize the patient before anesthesia should be taken



COMMENTS

Patient Monitoring

- Monitor blood urea nitrogen, creatine, phosphorus, packed cell volume, urine output and urine specific gravity, coagulation profiles throughout the course of treatment.
- Monitoring clinical signs of anemia such as respiration rate, heart rate, and energy level may help in deciding if a blood transfusion may be necessary.

Prevention/Avoidance

- Inform client about the hazards of ingesting zinc-containing objects and to avoid using zinc oxide ointments.

Possible Complications

- Sequelae include DIC and multiple organ failure with cardiopulmonary arrest.

Expected Course and Prognosis

- Supportive care may be needed for several days to weeks.
- Prognosis depends on the severity of clinical signs and patient response to treatment.

Abbreviations

- ALP: alkaline phosphatase
- ALT: alanine aminotransferase
- DIC: disseminated intravascular coagulation
- EDTA: ethylenediaminetetraacetic acid
- FDP: fibrin degradation products
- IM: intramuscularly
- IV: intravenously
- pH: acid-base
- PO: by mouth
- PT: prothrombin time
- PTT: partial thromboplastin time
- PU/PD: polyuria/polydipsia
- RBC: red blood cell
- SQ: subcutaneously

Suggested Reading

- Cahill-Morasco, R, and DePasquale, MA. Zinc toxicosis in small animals. *Compend Contin Educ Pract Vet* 2002;24:712–720.
- Gandini, G, and Bettini, G, et al. Clinical and pathological findings of acute zinc intoxication in a puppy. *J Small Anim Pract* 2002;43:539–542.
- Macintire, DK, Drobatz, KJ, Haskins, SC, and Saxon, WD. *Manual of Small Animal Emergency and Critical Care Medicine*, pp. 397–398. Philadelphia: Lippincott Williams and Wilkins, 2005.
- Mikszewski, JS, Saunders, HM, and Hess, RS. Zinc-associated acute pancreatitis in a dog. *J Small Anim Pract* 2003;44:177–180.
- Richardson, JA, Gwaltney-Bryant, SM, and Villar, D. Zinc toxicosis from penny ingestion in dogs. *Vet Med* 2002;97:96–99.

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Acknowledgment to original author in *Blackwell's Five-Minute Veterinary Consult: Canine and Feline*: Patricia A Talcott

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